AD-A048 645 B-K DYNAMICS INC ROCKVILLE MD F/G 5/9
ADVANCED TECHNOLOGY MANPOWER FORECASTING. NAVAL REQUIREMENTS FO--ETC(U)
DEC 77 P COOK, T P KANE, R MCQUIE N00014-77-C-0026
UNCLASSIFIED BKD-TR-3-235 NL

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Advanced Technology Manpower Forecasting.

Naval Requirements for Skilled Manpower and the Introduction of New Technology.

9 FINAL REPORT. 22 Oct 76-
31 Oct 77,

B-K Dynamics, Inc.
15825 Shady Grove Road
Rockville, Maryland 20850

Prepared Under Contract Number 15 N00014-77-C-0026

11 30 Dec[redacted] [redacted]77

12 65 p.

PREPARED FOR THE

OFFICE OF NAVAL RESEARCH
800 N. Quincy Street
Arlington, Virginia 22217

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER BKD TR-3-235	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Advanced Technology Manpower Forecasting		5. TYPE OF REPORT & PERIOD COVERED Final Report 22 Oct. 1976 - 31 Oct. 1977
		6. PERFORMING ORG. REPORT NUMBER BKD TR-3-235
7. AUTHOR(s) Pamela Cook, Timothy P. Kane, Robert McQuie		8. CONTRACT OR GRANT NUMBER(s) N00014-77-C-0026 New
9. PERFORMING ORGANIZATION NAME AND ADDRESS B-K Dynamics, Inc. 15825 Shady Grove Road Rockville, Maryland 20850		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 347-039
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 31 December 1977
		13. NUMBER OF PAGES 57
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DDC
JAN 6 1978
F

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Manpower Forecasting
Forecasting by Disaggregation
Forecasting by Linear Programming
Manpower Projections

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study investigates the feasibility and usefulness of forecasting techniques applied to the manpower requirements and research and development planning and programming cycles. A major thrust of the effort is directed towards creating data bases in computer and nuclear manpower requirements from 1950 to the present, 3rd generation computer, nuclear, laser, and electro-optics technologies, and 24 weapon systems (aircraft, ships, and bases) from 1946 to the present. Three methodologies are used to forecast

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S/N 0102-014-6601

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manpower requirements for emerging technologies. Growth curves and historical analogies are used to forecast manpower requirements based on similarities between existing and emerging technologies which are useful in validating more complex forecasting techniques. A system disaggregation technique is used to analogize manpower requirements on a component by component basis compared between an existing reference system and a perceived application of a new technology. A linear program allocates manpower over a 30-year period to forecast changes in the number of skills required by the addition or deletion of technology represented in the 24 weapon system types.

TR-3-235

Advanced Technology Manpower Forecasting

Naval Requirements for Skilled Manpower and the Introduction of New Technology

FINAL REPORT

B-K Dynamics, Inc.
15825 Shady Grove Road
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Prepared Under Contract Number N00014-77-C-0026

30 December 1977

Approved By:

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ADVANCED TECHNOLOGY MANPOWER REQUIREMENTS

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ADVANCED TECHNOLOGY MANPOWER REQUIREMENTS

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ABSTRACT

The study investigates the feasibility and usefulness of forecasting techniques applied to the manpower requirements and research and development planning and programming cycles. A major thrust of the effort is directed towards creating data bases in computer and nuclear manpower requirements from 1950 to the present, 3rd generation computer, nuclear, laser, and electro-optics technologies, and 24 weapon systems (aircraft, ships, and bases) from 1946 to the present. Three methodologies are used to forecast manpower requirements for emerging technologies. Growth curves and historical analogies are used to forecast manpower requirements based on similarities between existing and emerging technologies which are useful in validating more complex forecasting techniques. A system disaggregation technique is used to analogize manpower requirements on a component by component basis compared between an existing reference system and a perceived application of a new technology. A linear program allocates manpower over a 30-year period to forecast changes in the number of skills required by the addition or deletion of technology represented in the 24 weapon system types.

ADVANCED TECHNOLOGY
MANPOWER REQUIREMENTS

I. INTRODUCTION

A. Background

1. Forecasting Requirement. The Navy does not now have an adequate way to measure qualitative and quantitative personnel requirements for ships and aircraft that will be operational in the mid- and long-range periods. Highly competent technicians require long lead times to acquire, train, and assign technical experience even when the Bureau of Personnel knows the type and number needed. The problem is compounded when new systems enter the fleet and inadequate means exist to anticipate the import of advanced technology applications.

With no means to measure the impact of technology, as it is being developed, on manpower there is no feedback to weapons systems developers through program managers who can request alternative designs with a more favorable manpower impact. Currently, manpower impact statements are not felt by systems developers until after DSARC III and as late as three years after Initial Operational Capability when contractor maintenance empirical data is supplied.

The reduction of man-hours required to operate and maintain the fleet is a recognized CNO objective. While certainly in part based on cost of personnel (some 65 percent of the total Navy budget), an even greater concern is the availability or supply of men and women in both numbers and quality. The Chief of Naval Recruiting and the Office of Naval Research have expressed concern over high recruit training attrition and the trend towards proportionately fewer mental groups I and II accessions compared to enlistees during the draft environment. Therefore, a need exists to forecast early in the technology development cycle (late 6.2, early 6.3), the impact of technology on manpower requirements to provide some information on the efficacy of possible applications with a view towards assessment of the aggregate effects of all ongoing development programs and on individual assessments of one project. A means to measure the impact of technologies now being developed on a future Navy which is attracting recruits who are tending to test less well than their pre-volunteer counterparts is needed.

2. Related Efforts. Because of the conflict between private sector demand and military requirements, ONR is actively investigating and defining methodologies to forecast the domestic labor supply and commercial and industrial demand for that labor. The eventual goal is to be able to identify and project the dimensions of the manpower pool available to the Navy over a five-to-ten year planning period. ONR's first step is to link the Urban Institute's Race-Age-Sex-Search-Turnover Model (RASST) with the Wharton Quarterly Model of economic output. The RASST model forecasts employment and unemployment for 16 race-age-sex groups. The Wharton Model produces an industrial breakdown of employment into nine sectors. The joint output will be a five year projection which will produce a demographic breakdown of employment and labor force participation by the 16 race-age-sex categories, as well as an industrial breakdown of employment. Particular attention is

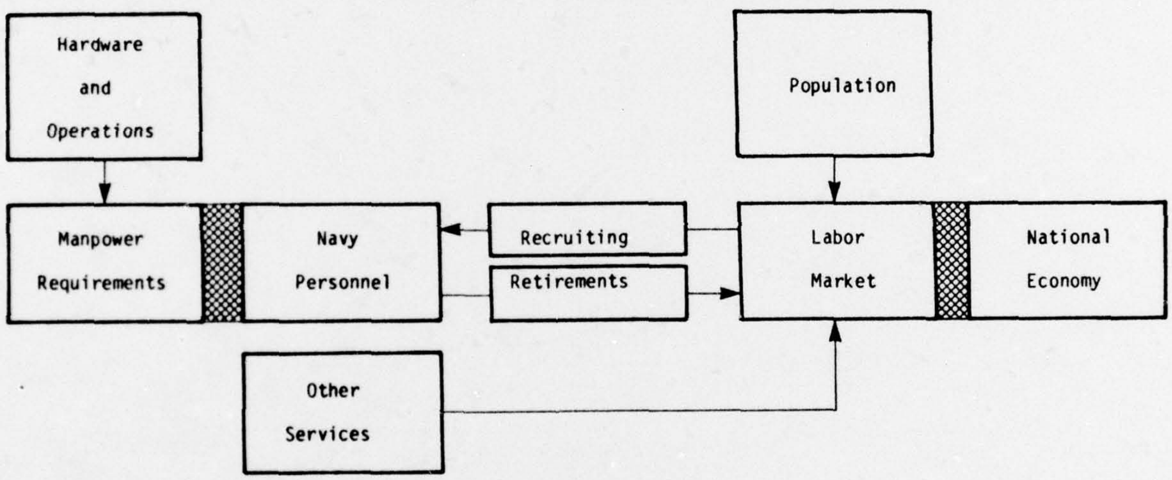
employment and labor force participation by the 16 race-age-sex categories, as well as an industrial breakdown of employment. Particular attention is being given to the participation rates of ten demographic groups as the likely source of enlistees.

Illustration I-1 depicts the major segments, interactions, and influences on the Navy's ability to man its requisite billets.

The effort herein described is collateral to the above demographic projection efforts, but part of ONR's attempt to develop research tools to meet changing technical, operational, and economic conditions.

ILLUSTRATION I-1

Naval Manpower Demand and Supply



3. Tasks. The goal of this effort is the assessment of the feasibility and usefulness of identifying advanced technology impact on manpower requirements in the future time frames (1981-2001). The initial objective in this effort is the assessment of manpower requirements in quantitative and qualitative terms based on advanced technology forecasts (evolutionary) in an individual weapon system context and a total force context. Specifically the tasks are:

- Forecasting Individual Weapon System Requirements Analogy Approach. Perform a historical pattern analysis of the directly related manpower requirements based on two existing technologies' expansion from inception to 1986. In this way, the actual manpower patterns can be checked against projected patterns and an assessment made of the adequacy of the forecasting methodologies used over the historical years. Then analyze the significant commonality of manpower requirements among the existing two technology fields. If sufficient commonality exists, then analogize

the manpower patterns of the new technology fields relative to past development of the baseline fields. Finally, perform dynamic trend extrapolation on the baseline fields from 1969 to 1975 and, if valid, apply the techniques to the new technology fields starting in year 1984 with 1976 through 1983 corrected from the static projection, the correction factor being the different policy/allocation sets selected for the out-years.

- Disaggregate Approach. Describe an inquiry structure and appropriate system functional disaggregation to isolate differences among existing technology applications and proposed new technology applications to highlight the critical new component or subsystem as the possible change in manpower requirements.

- Forecasting Total Force Requirements. Describe and validate a forecasting methodology that assesses the Navy-wide manpower impact of the introduction of one or more technologies into the fleet.

- Application of the Forecasts. Identify potential users and the usefulness of advanced technology manpower requirements data in terms of timing, level of detail, and accuracy required.

B. Problem

1. Scope of Effort. The application of technology to ships, aircraft, weapons, and supporting technology is made possible by a concert of technology developed programs beyond the Navy alone. Many major developments made available to the Navy come from DoD, other services, and especially the private sector. The Navy's RDT&E program consists of 600 task areas subdivided into 3,000 work units, each with some potential for changing current practices or current hardware.

The Navy's one-half million man force with 85 ratings or skills, on the whole, interacts to some degree with technology. Of those that directly interface with technology, about 30 percent are operators and 70 percent are maintainers. The total force is derived from an iterative process among DoD's perceived responsibilities, Congressional allocations among competing needs, and the Executive fulfillment of a defense strategy. The Navy's response to its assigned roles and missions is a weapons program balanced between capability and threat. Manpower requirements are a reflection of the need to man the billets of the selected weapons and supporting services.

While there is a direct relationship between the quantity and skills of operators and the number and types of weapons, the relationship is less direct for maintainers. With 70 percent of the enlisted force involved in maintenance and supporting services, a majority of manpower requirements are more directly related to logistics and maintenance strategies than operator needs per se. A significant alteration in maintenance and logistic strategies could have as profound an influence on total force requirements - in both quantity and quality - as major technological innovation. It is more likely than not that the Navy in the year 2000 will have less shipboard maintenance

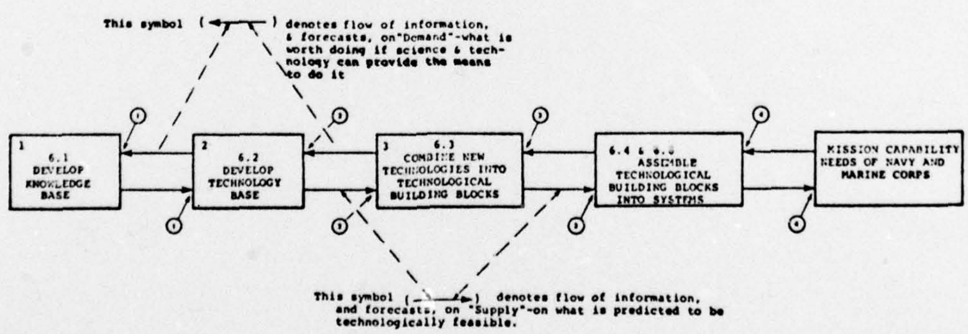
than it now has, and among its land based maintenance team, it will have more civilians comprised of both Navy and contractors than it now has.

This study is concerned with the total numbers and skills required to perform the running of the Navy, but it is indifferent to who does it - Navy military, civilians, or contractors. The Total Force Requirements Forecasting Methodology states what the distribution of skills and numbers could be with the introduction of one or more technologies based on the assignment of skills to old technologies. The support tail is directly related to the platform or technology and not distributed between sea and shore. One Individual System Forecasting Methodology relates one technology and its directly attributable skill without addressing any characteristic distribution or utilization of that skill (nuclear propulsion-nuclear ratings). The other Individual System Methodology concerns itself only with the skill required and not numbers associated with a component or subsystem change due to new technology in an existing weapon system or uniquely identifiable functional grouping of hardware.

2. R&D Cycle and Manpower Requirements. To be useful, a manpower forecast must be able to influence the weapon system developers. Assuming the forecast is reliable and relied on, the manpower impact data must be available when the system specifications can be reasonably altered to function with more or less manpower. Illustration I-2 depicts the RDT&E process and the ingestion points for manpower requirements information in various indicated formats. Forecasts from the Individual Systems Methodologies are useful at 2 and 3 points. The Total Force Requirements Forecast is helpful to the 2 points. The needed time domain, level of detail, and accuracies required by the potential users influenced the selection of methodology approaches and the emphasis placed on their development.

ILLUSTRATION I-2

Functional View of the Defense RDT&E Process



NEEDED MANPOWER PROJECTIONS

1. Technological Impact In General Manpower Fields
2. Grade Distribution for New Weapon Systems, i.e., Officer, Petty Officer, Seaman Ratios For A Given New System Like The Aegis Ship
3. Program Objective Memorandum, Manpower Which Gives FY DP+2 Years Data
4. Personnel Distribution By Skill and Grade

3. Objective. This study selected, applied, and validated several manpower forecasting methodologies to assess the feasibility and usefulness of measuring the impact of advanced technology on manpower requirements. Since the literature is not encouraging on the success of past manpower forecasting efforts, this study necessarily limited itself to three methodologies and five technologies with an emphasis on validation of the forecasts.

C. Approach

1. Micro-Individual Systems Forecast

(1) Graphic Analogy

For purposes of exploiting present technology forecasting techniques on future manpower requirements predictions, methodologies presently in use have been selected. One is a static projection by historical growth analogy combining dynamic trend extrapolation by curve fitting. With this approach, policy and allocation assumptions permit a range of options with each option varying on the number of uncontrollable factors. The reliability of the methodology is measured by the consistency of the results over many iterations of the problem. Ultimately, the goodness of results depends on the forecasters' judgment in quantification. Static projections are constrained by present policy sets and are accepted as reliable for three to eight years in the future. Beyond that point, present policy or resource allocation issues normally develop projections that are less than reliable. Consequently, dynamic extrapolation normally commences at future year points. Dynamic methodologies are characterized by the quantification of controllable factors.

(2) System Disaggregation Analogy

The functional disaggregation of an existing system into its component parts and substituting the new technology into its proper structural form is another static methodology for manpower forecasting which is derived by analoging the existing manpower requirements adjusted for the changes in numbers or skills of manpower associated with the new technology component. It is extremely reliable when there are few component changes and denigrates rapidly when significant numbers of components are replaced because of the difficulties of assessing, by analogy, the synergistics effects of multiple technologies in one system.

2. Macro-Modified Linear Program. This dynamic methodology was selected during the course of the study as a direct result of the Phase II inquiry into the potential users of manpower forecasts.

A standard computerized linear program was modified to allocate manpower skill levels over an array of ships, aircraft, weapons, and bases characterized by their technology. The model assumes an implicit relationship among these variables and a direct relationship among distributable skill levels. For validation purposes, the 85 ratings were aggregated into three skill groups. Total Navy requirements for the years 1945 through 1975 were distributed over existing and planned "technologies" to determine the ratios of high, medium, and low skill groups required for that technology based on past skill distributions.

3. Technology Areas. There are three basic elements to forecasting: methodology, forecaster, and data. A reliable data base is available for the technology areas of computers and nuclear propulsion with respect to both technology expansion and manpower requirements from inception of the technology in the late 1940s to present programs for the near future (1986). The advanced technology areas of electro-optics (E-O), lasers, and phased array radar (PAR) have approximately ten years of history from their basic research breakthrough with five years experience in advanced development. They are presently primary components of programmed future weapon systems. All were selected based on familiarity and potential for impact.

II. DISCUSSION

A. Methodology Selection Process

1. Literature Search. Much theoretical work has been done in both manpower forecasting and technology forecasting. Illustration II-1 depicts the scheme of various possible approaches. The objective in this effort was less methodology development than empirically validating several acceptable forecasting techniques. Two manpower forecasting surveys were relied on for evaluation of the most appropriate techniques: Patter's Methods for Predicting and Assessing the Impact of Technology on Human Resource Parameters, and Kelley's An Evaluation of the State of the Art.

ILLUSTRATION II-1

Technological Forecasting Taxonomy

EXTRAPOLATION

JUDGMENTAL

- Polls
- Panels
- Delphi

PROJECTION

- Regression
- Biological Growth
- Economic Growth

ANALOGY

- Correlation
- *Curvilinear Correlation*

NORMATIVE

NETWORK CONSTRUCTION

- Morphological
- Decision Trees
- *Functional Array*

MATRIX CONSIDERATION

- Cross Impact
- Mission Network
- Systems Analysis

Neither these surveys nor other literature reviewed provided a solution to the problem of forecasting manpower requirements based on emerging technology. Nearly all efforts in the field have been theoretical or descriptive. Of 80 dissertations reviewed, only two studies attempted an application using empirical data, but both were unsuccessful due to data limitations.

There is no one best forecasting method, whether extrapolative or normative. The selection is determined by the data of immediate concern; the same technique may produce forecasting errors for other aspects of the data. The selection of a technique required a great deal of analysis of the data and a comparison of various possible methods. It is interesting that much of the effort of forecasting, after data assembly, is aimed at analyzing the forecast errors. Since one major aspect of the effort is the forecasting of manpower requirements for new technology as early as possible in the development cycle, lead time errors of seven years were of practical interest. The second point of interest is that later forecasts were much better than earlier forecasts, indicating that familiarity with the data is

important. Finally, while many forecasting techniques tend to be simplistic and, therefore, implicitly less credible, graphic and historic analysis was essential in providing some variables and validating the results of the more rigorous linear program forecast. It is intuitively unwise to use the same forecasting technique to produce variables for a needed forecast.

2. Data Sources. The major part of this effort was data collection and analysis. The data needs of the linear program are comprehensive in scope and detailed in depth. The appendix to this report details the data used in the macro forecast. The following list is representative of the general material used. Section II-D discusses some of the problems with conflicts and non-availability of needed data. One insurmountable problem with the System Disaggregation approach here is the classification of data. Although available, they are not included because of security restrictions.

General Reference Material

- Industry promotional periodicals such as Laser Focus, Electronics, and Computer
- Burea of Personnel's Official Statistics published in MARP 1300.1 (Green Book)
- Department of Labor, Bureau of Labor Statistics' publications
- Unpublished material from Navy Historical Museum
- U.S. Navy official unit diary summary, unpublished memos, Bureau of Personnel Library.

B. Graphic Analogy Technique

1. Concept. The objective of selecting this technique was to develop a growth pattern for existing technologies to provide insight for analogizing manpower requirements to emerging technologies. The primary comparison between the mature technology and the emerging technology was to be by historical analogy. The relative success of this appraoch is independently less important than the insights that it provides for the more complicated technique of linear programming.

Various growth curve models, such as exponential, Gompertz, and logistic were used. The problem of deciding from a set of data which curve is appropriate was decided by plotting on graph paper to arrive at a straight line. Also, slope characteristics were identified. Various slope equations are available, and once fitted, provided the appropriate linear trend. These methods depend upon the smoothness of data in order to deal with two practical problems. There is first the problem of measuring the slope at different times. This is important here because two technologies developed independently at different times are being compared. This is resolved by

smoothing with a moving average. Secondly, the fact that the method depends on eye comparison to see which looks most like a straight line can lead to difficulties, especially when the vertical scales are all in different units.

The important element of growth curves is that they can be transformed either to a linear or simple exponential model. The linear form was used as the basis for extrapolation. This method does require a very small random component superimposed on the growth curve to avoid poor forecasts (Gilchrist). All transformations here were based on data with exponential characteristics and were taken by logs. A least squares was fitted and antilogs taken to give the fitted exponential growth curve. The bias, which increases with the standard deviation, proved to be non-systematic. However, standard deviations tended to be small due to smoothing and institutional characteristics of the data, such as fixed percentage increases in programmed dollars for specific technologies.

Most manpower forecasting literature supports using economic tools. In addition to the mathematical tools discussed above, the applicability of various input-output models was considered. Agarwall asserts that manpower demand represents requirements of skill-mix against specific levels of technology and productivity. Changes in technology, productivity, and skill composition go hand in hand, but the interrelations are flexible because of substitution between capital and labor, between different skills, and between education, training, and experience of personnel. This intuitively correct production model was modified by Stainer to include the concept of technical dynamism expressed as an exponential over time. However, Kelley suggests that the rate of change of technology is dependently related to the productivity rate of labor. Therefore, Kelley questions the efficacy of the productivity rate (dollar output per unit input) used in all Cobb-Douglas production function models for manpower forecasting. Kelley concludes that the real difficulty in manpower forecasting is the structural and institutional form of the input data and not theoretical formulations.

The linear program used in the macro technique does reflect the general form suggested by Kelley without explicitly dealing with productivity rates.

2. Data. Information was compiled on four of the technologies of interest both to gain insight into different aspects of their historical growth and to provide data for establishing causative relationships. Illustration II-2 is representative of data compiled from various industrial publications and unpublished government working papers. All dollars here and elsewhere have been adjusted by the Labor Department's GNP inflater.

ILLUSTRATION II-2

U.S. R&D and Sales Selected Electronics Technologies (in millions) (1967 = 100)

	DoD ELECTRONICS			DIGITAL			NUCLEAR INSTRUMENTS		
								FEDERAL GOV'T	
YEAR	PROCURE-MENT	RDT&E	ELECTRO-OPTICAL	ADP SYSTEMS	LASERS	COMMUNI-CATIONS	INDUSTRY	PROCURE-MENT	RDT&E
1951									
1952									
1953									
1954									
1955									
1956				261.		326.			
1957	4601.	317.		412.		405.			
1958	5072.	575.		259.		366.	52.		
1959	5123.	1067.		429.		180.	61.		
1960	5240.	846.		609.		187.	66.		
1961	4855.	2258.		903.		772.	96.	11.	5.
1962	5468.	3348.		1060.		999.	123.	29.	14.
1963	4964.	2125.		1427.		852.	112.	42.	18.
1964	4907.	2172.		1588.	4.	978.	113.	65.	36.
1965	4402.	1949.	79.	1596.	27.	1291.	137.	70.	32.
1966	4596.	2034.	98.	1751.	35.	1211.	142.	67.	33.
1967	4916.	2245.	19.	2420.	52.	912.	114.	70.	35.
1968	4371.	2188.	22.	2937.	53.	1198.	122.	67.	33.
1969	4243.	2070.	47.	3751.	58.	1202.	115.	65.	32.
1970	3984.	2111.	31.	2977.	58.	1288.	177.	58.	29.
1971	4131.	2138.	33.	3444.	28.	1085.	32.		--
1972	4152.	2181.	45.	4391.	28.	1333.	35.		--
1973	3803.	2090.	48.	4931.	29.	1514.	24.		--
1974	3682.	2237.	54.	4624.	30.	1525.	26.	7.	--
1975	3789.	2421.	47.	3607.	30.	1404.	28.		15.
1976	3948.	2570.	51.	3715.	33.	1513.	28.		35.
1977	7051.	4945.	104.	7312.	62.	2912.	52.		73.
1978	7570.	5143.	119.	8474.	69.	3239.	55.		79.
1979	8089.	5341.	134.	9637.	76.	3566.	59.		88.
1980	8608.	5538.	149.	10800.	82.	3893.	62.		92.

Computer and nuclear reactor time lines are presented in Illustrations II-3a and II-3b to provide background on qualitative growth pictures and possibly a rationale for variations in known manpower and dollar growths.

ILLUSTRATION II-3a

Computer Time Line

1937	IBM MARK I development began (AIKEN)
1942	MAUCHLY/ECKERT ENIAC began - Army funding
1944	MARK I complete
1945	ENIAC devel. complete - military application
1946	ECKERT - MAUCHLY Computer Corporation - Univac Contract with Census Bureau
1950	E-M Merger with Remington Rand - Univac Division
1951	Univac I given to Census Bureau in 1951
1949	Stored Program on Cambridge England machine 1949
1953	IBM 701
1954	IBM 650
1956	Total value of installed computers - $269M IBM 75.3%, Sperry-Rand 18.6%, Burroughs 4.4%, RCA 1.6%, NCR .1%
1957	CDC break-off from Sperry-Rand
1958	Univac solid-state 80 transister technology
1959	IBM 7090 (solid-state 709)
1959	Total value of installed equipment - $1B
1958-1960	Tubes, Transistors
1959	Digital Equipment Company PDP-1 delivered
1959-1965	2nd generation transistor computers
1960	CDC 1604
1964	Honeywell H-200; 1401 Replacement
1964	Integrated circuits (TI, Fairchild); third generation
1964	360 IBM - by bid integrated circuits
1965	360s delivered
1966	Integrated circuits competition with other technology
1967	Time-sharing system from GE
1968	CDC 7600
1970	GE-Honeywell merger
1971	RCA sellout to Sperry-Rand

ILLUSTRATION II-3b

Nuclear Reactor Time Line

1942	Hanferd test bed critical
1942	Hanferd production reactor started
1944	First production reactor
1951	EBRI (Argonne, Idaho) first power generator breeder
1953	Submarine reactor (Idaho Falls)
1955	Nautilus sea trials
1957	Shippingport commercial power generator

Illustrations II-3c and II-3d show the naval requirements for digital computer and nuclear reactor personnel. The Navy does not now have military personnel trained in laser, phased array radar, nor electro-optics as an identified subspeciality.

ILLUSTRATION II-3c

U.S. Navy Digital Computer Manpower Requirements

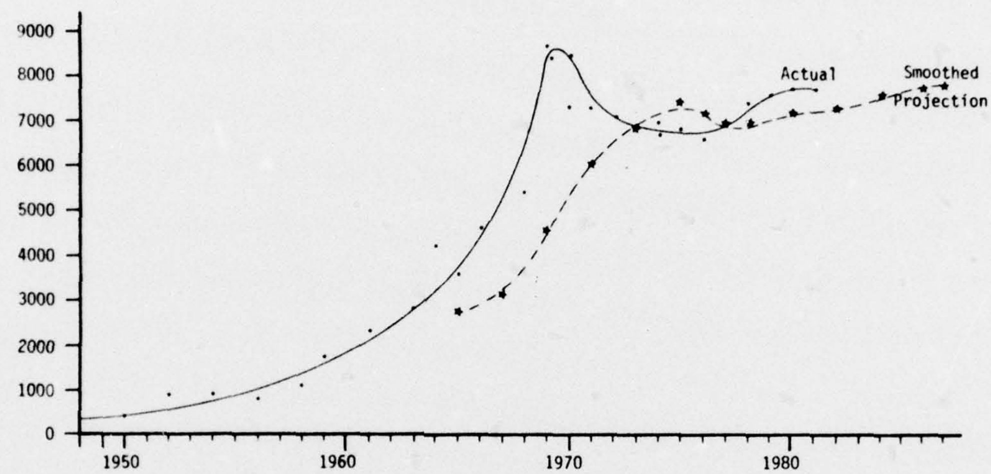
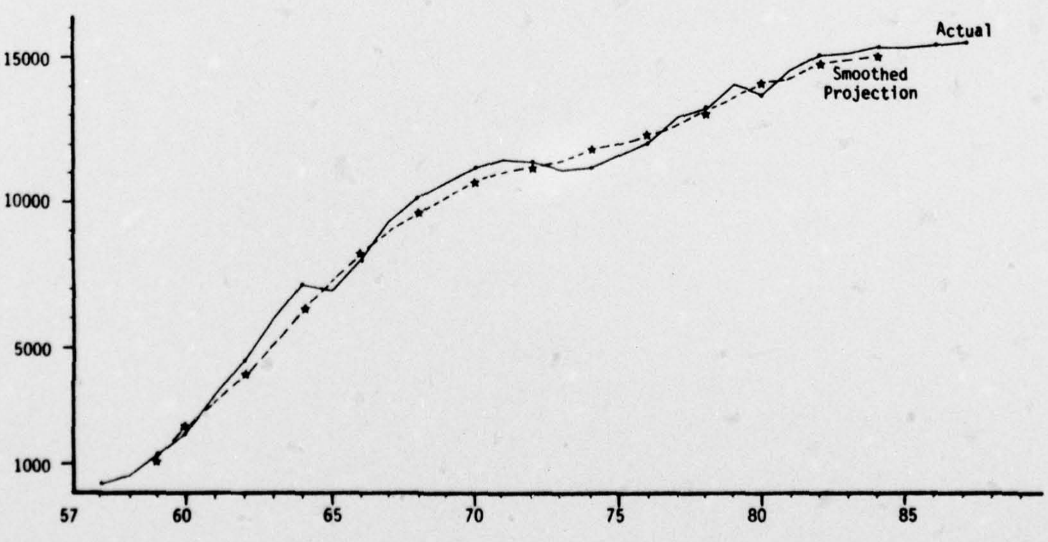


ILLUSTRATION II-3d

U.S. Navy Nuclear Technology Manpower Requirements (1954-1987)



3. Application. Various curve fitting techniques were applied to exponentially and linearly smoothed data to identify the most appropriate curve for each set. Visual identification was tried as well as slope equations. Nuclear manpower requirements were exponential in form, therefore, a dynamic growth projection was made using a least quares method to determine estimates of the forecasted x-axis intercept and slope. A similar procedure was used on computer personnel using a Gompertz curve model. Both results are shown on Illustrations II-4a and II-4b.

ILLUSTRATION II-4a

U.S. Navy Nuclear Manpower Requirements

Ship Type / Year	SSN	SSBN	FBM	CVN	CGN	DLGN	AS	SUPPORT	TOTAL
1954	45							40	85
1957	135							121	256
58	225	53					30	277	585
59	360	159			121		60	630	1330
1960	495	318			121		118	958	2010
61	720	477		114	242		182	1735	3470
62	810	848		114	242		246	2260	4520
63	855	1537		114	242		278	3026	6052
64	1035	1749		114	361		310	3569	7138
65	1035	1961		114	361		342	3145	6958
66	1170	2332		114	361		342	3618	7937
67	1440	2385		114	361		342	4642	9398
68	1755	2385		114	361		342	5071	10142
69	2115	2385		114	361		342	5431	10862
1970	2295	2385		114	361		374	5529	11172
71	2565	2385		114	482		406	5467	11419
72	2745	2385		114	604		406	5123	11377
73	2835	2385		114	604		406	4839	11183
74	2970	2385		114	723		406	4618	11216
75	3060	2385		235	844		406	4851	11781
76	3150	2385		235	966		406	4999	12141
77	3375	2385		355	1085		438	5346	12984
78	3510	2385	67	355	1085		470	5510	13382
79	3690	2385	134	355	1085	117	470	5765	14001
1980	3870	2385	201	355	1085	234	470	5160	13760
81	4050	2385	268	478	1085	351	470	5452	14539
82	4230	2385	268	478	1085	468	470	5630	15014
83	4320	2385	268	478	1085	468	470	5684	15158
84	4455	2385	268	478	1085	468	470	5765	15374
85	4455	2385	268	478	1085	468	470	5765	15374
86	4500	2385	268	478	1085	468	470	5792	15446
87	4545	2385	268	478	1085	468	470	5819	15518

ILLUSTRATION II-4b

U.S. Navy Digital Computer Personnel

Skill / Year	Machine Accounting man MA	Nuclear Weapons man NW	Communications Technician Mechanical CTM	Data Systems Technician DS	Data Processing Technician DP	TOTAL
1948	105					105
	-					-
1950	438					438
51	852					852
52	851					851
53	947					947
54	861					861
55	729					729
56	769					769
57	831					831.
58	1041	289				1330
59	1050	1145				2195
1960	1181	1145	550			2876
61	1226		621			1847
62	1412		706	139		2257
63	1872		935	330		3137
64	2111		156	506		2773
65	2190		1095	881		4166
66	1861		831	891		3583
67	2374		1187	1019	-	4580
68			1500	1176	2657	5333
69			3304	1618	3769	8681
1970			3304	1669	3434	8407
71			2355	1613	3285	7253
72			2072	1631	3325	7028
73			1887	1706	3416	7009
74			1646	1694	3654	6994
75			1604	1791	3342	6737
76			1646	1883	3052	6581
77			1651	2038	3148	6837
78			1844	2378	3181	7403
79			1863	2495	3195	7553
1980			1866	2596	3202	7664
81			1850	2614	3202	7674

Illustrations II-5a, II-5b, and II-5c are representative of attempts to establish visual similarities in historical growths for possibly analogizing manpower patterns. It is interesting that spending patterns on digital computer equipment did not suffer the same fluctuations that other selected industries did in the 1969 and 1973 general business downturns.

ILLUSTRATION II-5a

Computer Activity (Equipment Shipments) in $ Vs. Time

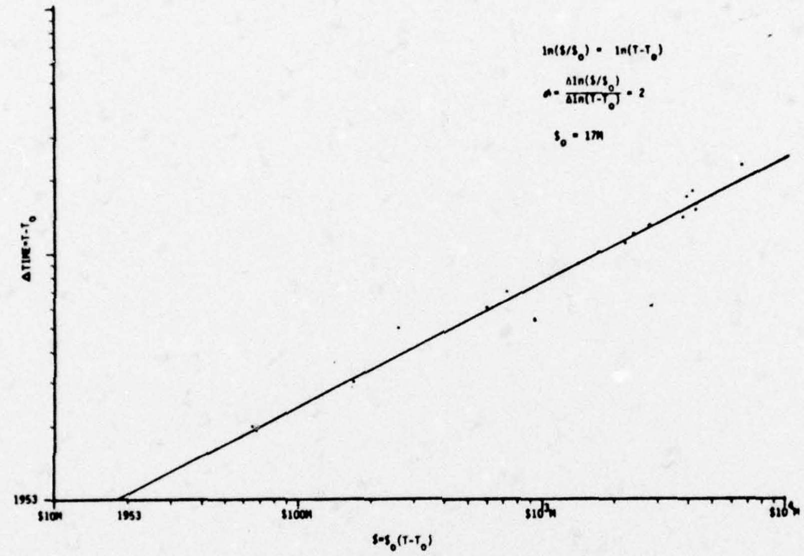


ILLUSTRATION II-5b

U.S. Commercial Digital ADP Revenue

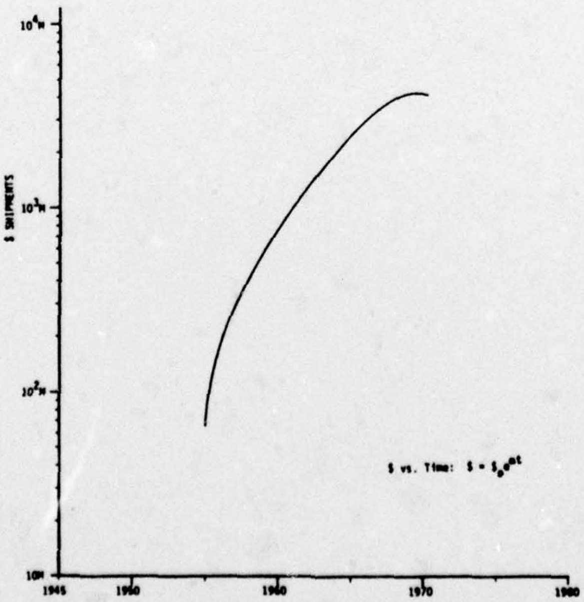
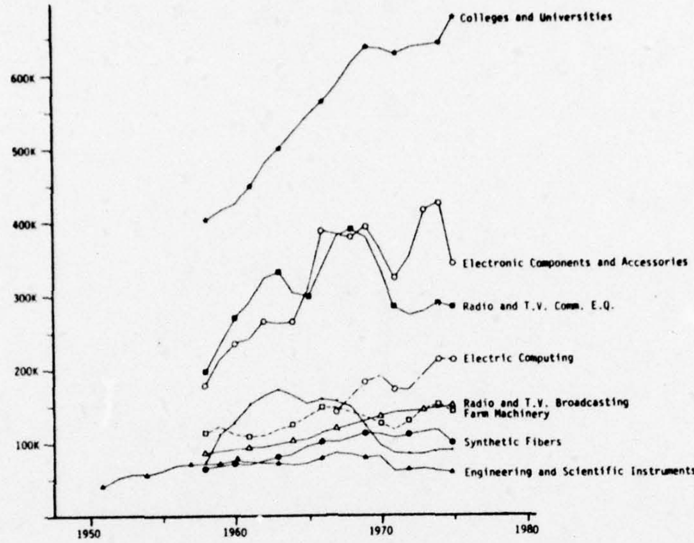


ILLUSTRATION II-5c

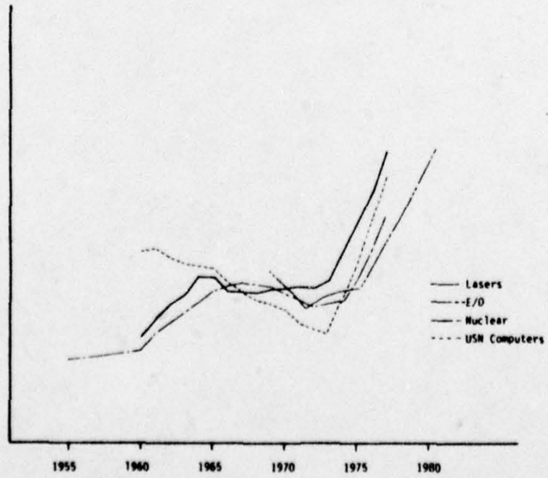
Breakdown of U.S. Commercial Revenue for Selected Items



4. Validation. The growth analogy technique was attempted to forecast existing technology manpower requirements and to relate, if possible, historical similarities with the three emerging technologies. Illustration II-6 indicates relatively similar spending patterns by the Navy for computer, nuclear, electro-optic, and laser technology. The curves are superimposed on the y-axis for comparative purposes. Any similarity is assumed to be structural and is certainly non-stable. The growth forecasts on nuclear and computer manpower had small non-systematic error and the bias acceptable. Both models compare well with static extrapolation based on a ratio of a constant man per unit.

ILLUSTRATION II-6

Smoothed Forecasts of Selected Technologies Superimposed



C. System Disaggregation Technique

1. Concept. Forecasting literature favorably supports normative rather than extrapolative techniques (Potter). Presumably this is because normative techniques are essentially inductive, specific, and mostly qualitative with the exception of decision network weighting factors. The functional disaggregation technique is normative and descriptive. It starts with a conceived or perceived application for the technology and works backward through the decision process to satisfy stated operational objectives. When the application is found acceptable both technically and operationally, an existing reference system is selected for the functional system comparison. This step is essential in identifying subsystems and components which serve two purposes. The first of which is to match common components, and the second is to isolate the new technology component. Thus, by analogy with manning requirements for the reference system, manpower for the new technology system is described. The manpower requirements for the component housing the new technology is described using standard Ship Manning Document rationale. The latter part of this approach borrows heavily from the Air Force's Qualitative and Quantitative Personnel Requirements Information which is oriented towards task analyses of new systems in the production stage of the R&D cycle. The generic disaggregation technique is depicted in Illustration II-7.

This disaggregation technique has the advantage of being adaptive by closed-loop feedback; it easily adjusts to changes in mission or employment of the technology; and it uses documents that are determinate of actual fleet manning. The technique does not address risks inherent in technology development nor is it concerned with the timing of the introduction into the fleet.

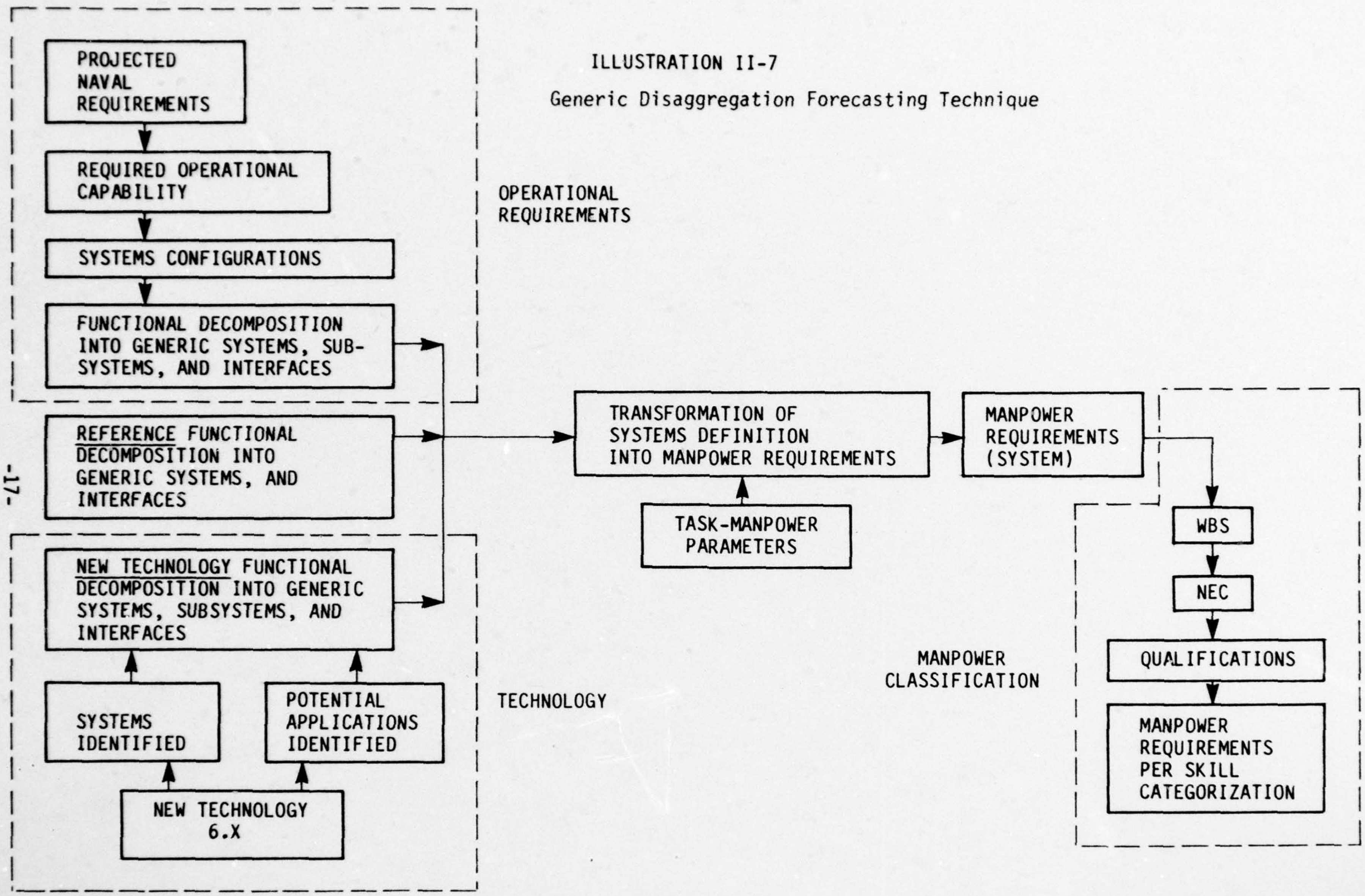
2. Data. This technique relies on technical documentation more so than other methods. The needed data comes from many offices, commands, and laboratories - from the Office of the CNO to the Enlisted Classification Branch. The data is broadly grouped into R&D management, reference system specification and ship manning - task analysis data.

Technology is developed in response to operational needs and these needs are stated in CNO's Required Operational Capability (ROC). CNM's response to these statements is the Science and Technology Objectives and the Navy Technical Strategies. If the strategies are ordered by mission, the technology thrust implicitly emerges. The thrusts can then be transformed into technology applications. This process is beyond the scope of this effort and is the subject of an intensive ongoing effort by CNM to establish a priority system for Navy R&D task areas. Until this is formalized, technology applications will have to be independently determined through techniques such as QUEST (NAVMAT-0312) which structures a weighting system to sedate technologies to science to missions. For purposes here, the aim is to identify the operational application of the new technology by considering the aspects of satisfying ROCs, filling technology gaps, and selection over competing means.

Reference system specifications are available through the appropriate program managers and system commands. Functional component descriptions proved to be the workable level of detail as opposed to detailed system specifications. For the example here, NAVELEX produced the component description of the SPG-55 radar which is a subsystem of the Terrier's Mark 76 fire control

ILLUSTRATION II-7

Generic Disaggregation Forecasting Technique



system. Component description of the perceived laser radar was developed with the assistance of Naval Sea Systems Command.

Ship (Squadron) Manning Documents are readily available and provide a reasonable means to analogize manpower requirements for components common to both the reference and perceived systems. A difficulty arises here in determining whether retraining existing skills, added personnel with upgraded skills, or completely new skills are required, but these are questions of classification and training and the basic question of what skill is needed can be derived.

3. Application. Most forecasting techniques require a great body of data in which familiarity helps shape the outcome. This technique does not have a historical perspective nor statistical basis. To create a framework and working environment before approaching the analysis, basic questions are asked:

- How is the technology defined
- How is manpower defined in terms of a given technology
- At what R&D phase can new technology systems be qualified
- What technologies are relevant to naval systems and manpower
- What are the operating system's characteristics that are determinative of manpower requirements
- To what extent should technology and manpower forecasts be tied to the naval R&D cycle.

For the most part, the questions are unanswerable and all but the first question will not directly influence the forecast. In perceiving an application for the technology, the definitional question may be most difficult. The R&D management documentation does not define technology which appears to be characterized more likely by funding source. Illustration II-8 depicts a taxonomy by program function, all of which terms describe work units under the heading of technology. This suggests that what is described as technology may not be technology at all.

ILLUSTRATION II-8

Program Technology Function

Fleet Operational Strategies	Characteristics Analysis
System Utilization Strategy	System Development
Methodology	Component Development
Application Identification	Interface Characteristics
Technology Based Large-System Application	End-Functions MOE Refinement
Application of Technology or other Measurements	Related System Support Development
Central Effects Studies	Support Data Base
Subsystem Utilization in Large Context	Material Studies
Feasibility Studies	(Sub) System T&E
Simulations	Performance Standards
	Extra-Technology Systems Analysis
	Administration

Illustration II-9 presents the expanded model used to assess high-energy laser (HEL) technology. The HEL application to radar satisfies a specific General Operational Requirement and the technology thrust is given focus by the Technical Strategy. The state of the art of HEL precludes it to a short-range system. Therefore, the Terrier's Mark 76 fire control system's SPG-55 radar was selected as the reference technology. The components for the HEL application were specified and compared with the functional description of the SPG-55. Illustration II-10 depicts those components deemed to be unique to an HEL radar set. The Ship Manning Document for a DLG with a Terrier system requires Electronic Technicians, Fire Control Technicians, and Radarmen. These ratings do not now receive training in HEL which replaces the SPG-55. The coherent receiver, analog processor, and modulator are well within the skill characteristics of general electronics ratings. The oscillator and laser generator are not. Specific task analyses must be performed to determine the estimated number of laser qualified personnel who will be needed on a given ship.

4. Validation. The disaggregation system is self-validating in accepting the need for specific skills given an applied technology. Errors can occur in two critical areas. First, if the technology is misapplied, then an invalid comparison will be made with a reference system. Second, insufficient information may be known to accurately specify the components of the perceived system application. Therefore, validation relies on the judgment of the technology developer. Here the validity of the forecast was accepted based on a consensus of naval laboratory personnel working in laser research.

D. Modified Linear Programming Technique

1. Concept. This project explored two approaches: an individual item of technology analysis and a Navy-wide analysis which involves examining the Navy's requirement for manpower at various skill levels for each year since 1943 and relating the number of personnel from each skill level associated with each technology system active in the Navy.

This section describes the research carried out in forming the concept of the approach in developing a macro-forecasting technique. Three tasks will be described. The first of these is determining, for the total Navy, the number of people required in each skill level. The second task is extending and correcting the counts of the number of each technology system for the years examined. The third task is the use of several different statistical tools to relate requirements to particular weapons systems.

For this preliminary analysis, 24 weapons systems were defined ranging from battleships to third generation computers, but they were primarily weapons systems.

Data on personnel requirements were accumulated only for the years 1944, 1952, 1957, 1962, 1967, 1972, and 1977. Estimates of personnel requirements for the other years were made by interpolation. Data on numbers of technology systems were accumulated for each year, but there were large gaps in some of the data series; these gaps were filled by interpolation.

ILLUSTRATION II-9

System Disaggregation Application

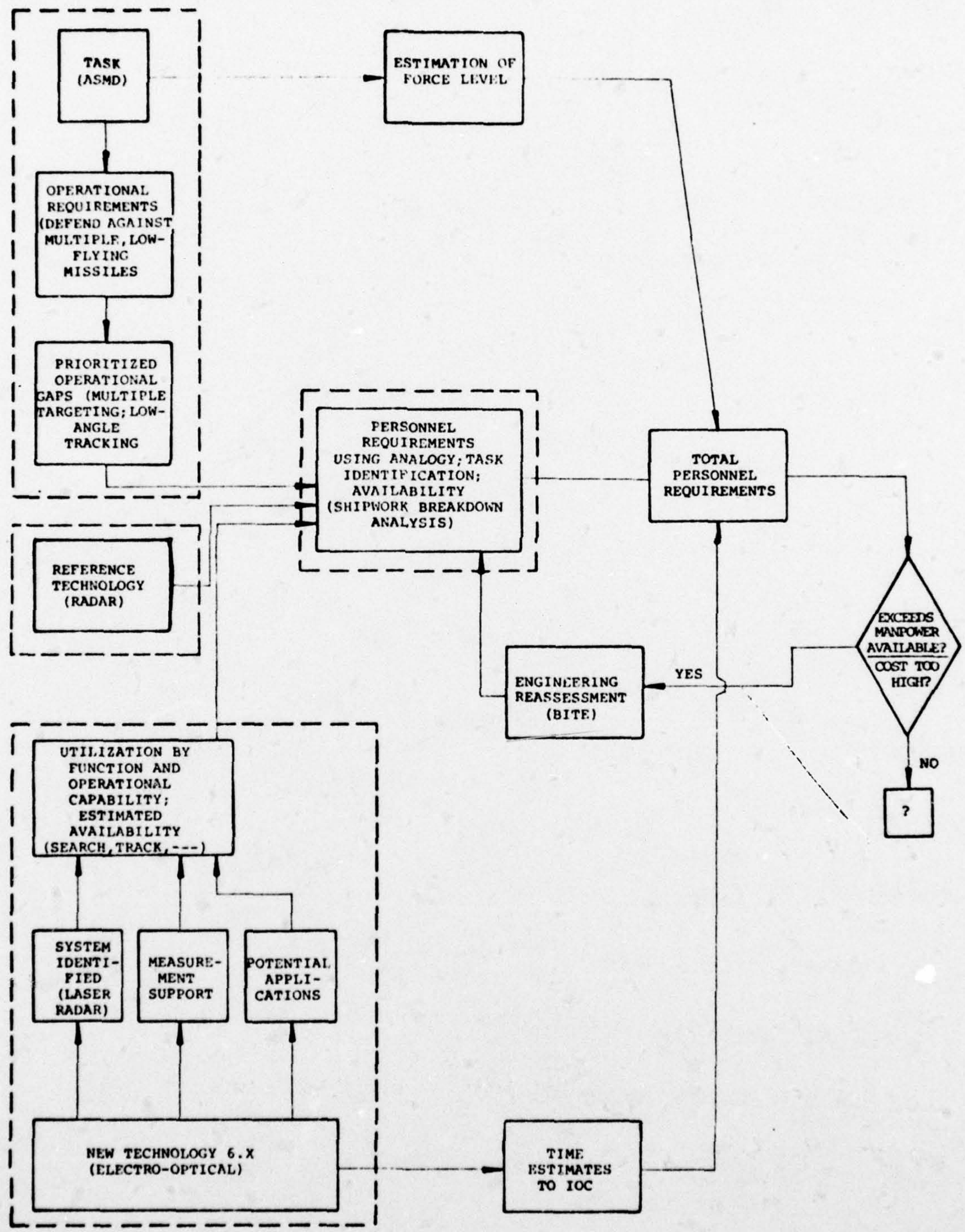
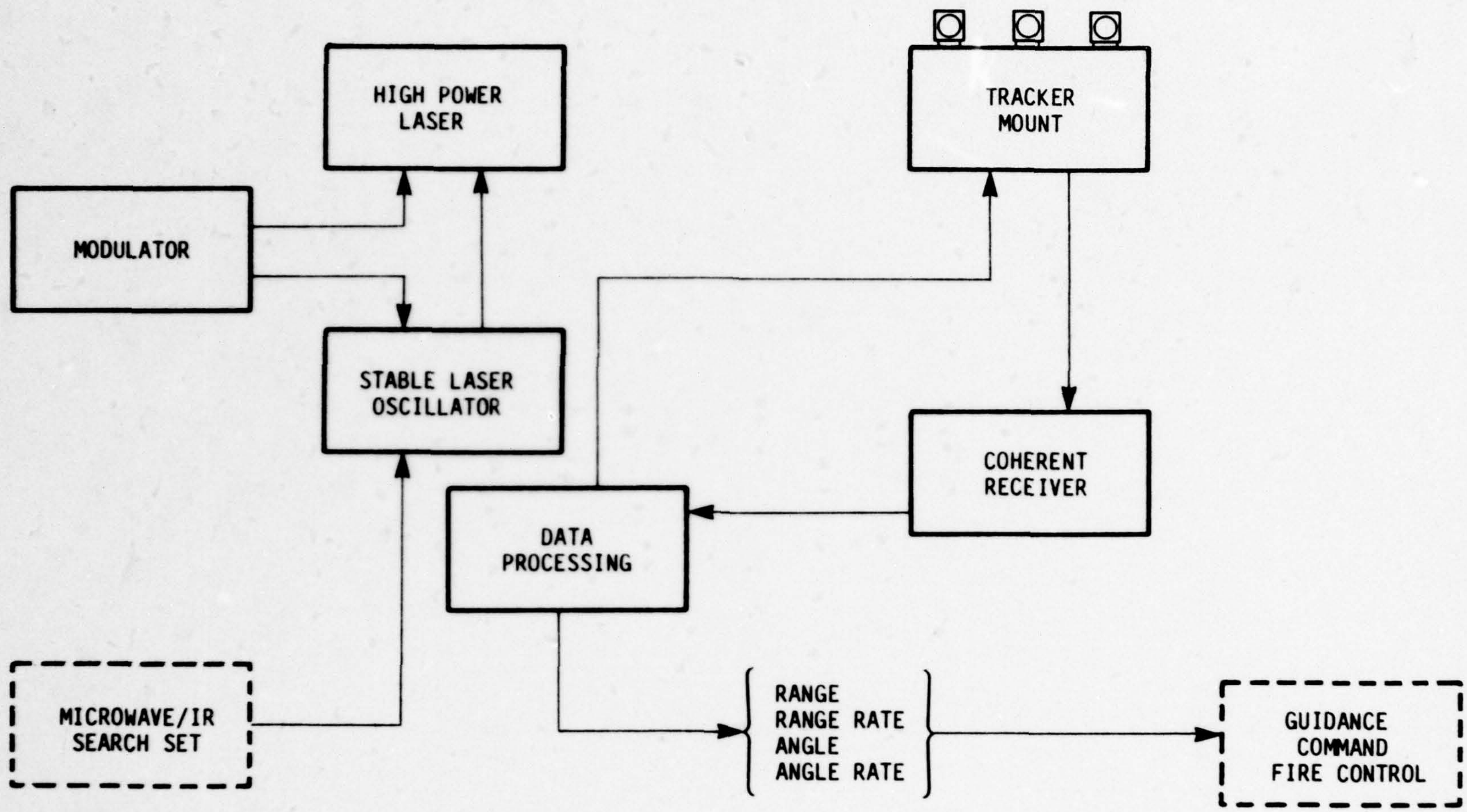


ILLUSTRATION II-10

Components Unique to A Mark 76 HEL Radar



The analysis involved apportioning the total number of personnel of a particular skill level and a particular year among the various weapons systems that were operational during that year. This was done by writing for each year an equation of the following type:

$$aX_1, + bX_2 + cX_3 + \ldots + xX_{24} + z = R_1$$

where X_o = # of systems of a particular type (input)
a = an unknown coefficient (output)
R_i = personnel requirement for a skill level (input)

In the above equation, the X's and R's are counts that differ for a weapon system from year to year. The lower case coefficients are the numbers of personnel associated with a weapon system as long as it is in the force and which does not vary from year to year. The z is the number of personnel in a particular year between the personnel required and the personnel that could be allocated to all technology systems being examined. The actual formulation of the analysis was somewhat more detailed than this brief description, but it is the essence of the approach.

Estimating the mix of required skill levels was arrived at by relating the skill level of each rating to the grade level of its non-military counterpart in the Navy civilian work force. The skill required of everyone in a rating was assumed to be the grade of the journeyman or fully qualified technician as specified by Civil Service Commission job evaluation standards. For the preliminary analysis, moreover, an assumption was made that the skill level of the ratings has not changed since 1943. That a steward in 1943 required the same level of skill as a mess management specialist in 1977 seems plausible. The same is likely to apply to the rating of boatswains mate. It is less likely to apply in the case of the quartermaster rating while in the communications and electronics ratings, the assumption may even be less plausible.

It was also assumed that the skill of a rating is the skill of its journeyman job. The historical patterns have remained relatively constant, therefore, the assumption is reasonable and should have the effect of nullifying any differences in skills mix from considering apprentice helpers or foreman (as their military equivalents) as different skill levels from the workers. The identical grade structures of all ratings, however, may not have been the case in the past, and this relation should be examined in future work.

An even better estimate of skill level for a rating might result if some of the Navy's computerized tools for personnel evaluation were used. There is an elaborate procedure for evaluation of the complexity of each military job, with the tasks performed by a rating evaluated by industrial engineers and stored in data banks. The contents of this data bank with respect to civilian grade levels appears to be the logical place to begin evaluating the complexity of manpower requirements. The overall system is called the "Computerized Factor Evaluation System" (CODAP), and it should be employed as far as possible in future efforts.

Another source of skill level evaluations is the decisions by the Navy Department and the Civil Service Commission about comparability between various military ratings and civilian jobs. One such decision was used here; it related to the Data Processing rating.

2. Data. The data used were, as mentioned above, incomplete in places. This was particularly true in terms of the various categories of aircraft examined. Because data for recent periods are classified, they were not used in detail here. Aircraft data for earlier periods are available in great detail, but tabulating them in usable form will take an understanding of both model types and the way aviation units are deployed. In the older reports, it is difficult to determine just what category of aircraft is being referred to, and in some places the definition of a category may have been changed without it being noted in the report.

The distinction between the total fleet of aircraft (including pipeline and planes in reserve storage), operational aircraft (including planes on loan to embassies), aircraft in operational units (including planes deadlined and in maintenance), operating aircraft (including training), and aircraft in combat and combat-related units (less than 10% of the total) becomes confused easily.

The aircraft categories themselves need additional thought. A distinction was made between combat, support and non-prop type planes with each category broken down into two classes (or variables): the older propeller driven type and the newer jet or rotary wing type. Once a start was made with these six aircraft variables, they were held constant, but the data discovered could probably be extracted more easily if different categories were used.

Data on ships in operation are also available in large quantities, and many of them have been published in quite widely used publications such as Jane's "All the Worlds Aircraft," Tabey's "Ships and Aircraft of the U.S. Fleet" and "Tlottes du Monde." Other data on ships are available in the Office of Naval History, the Navy Library, the Navy Aviation History Office, and the history offices of the various material commands. None of the sources agree, and the differences involved could contaminate future analysis because the number of ships involved in recent years has been small. Since an aircraft carrier is difficult to hide, the differences must be attributable to the way the data are reported rather than the condition of the fleet. Some reports in the past left some classes out of their final document while others included them. Research and special project submarines are examples of this. The change in the definition recently of cruisers, frigates, destroyers, and escorts makes careful and detailed tabulation necessary to get data that are comparable from year to year. In one place, the data used had to be based on actual hull numbers to get consistent data. Another area where some data used one definition and some used another relates to computers and the distinction between a "system" and a "mainframe."

Once the data have been assembled in a complete and fully understood table, they are ready to analyze. Even though these raw data do not answer the specific question posed for the study, they are nevertheless interesting and thought provoking. In this way, defects would be spotted and additional data brought to light. This requires preparation and definition of the

variables and detailed footnotes of the documents where each number is based on their location. Each variable, if plotted, would convey an otherwise unavailable picture of what has happened to the Navy in the last 35 years.

To relate numbers of people to number of systems, 34 years of counts of the number of technology systems and counts of the number of skill levels were prepared. Systems and skill level mixes change from year to year, but the rates of changes are different for each. One system, such as battleships, gradually phases out, while another, such as nuclear power carriers, phases in. In a particular year, each new system phasing in increases requirements while each old system phasing out decreases them. As a result, the number of personnel at a skill level changes from year to year. If the system of generating requirements is reasonably accurate, the above observation provides the basis for moving from the known total Navy requirements to the unknown requirement for an individual technology system. As long as there are more years than systems, the individual requirements may be estimated by solving some sort of series of simultaneous equations.

Several methods of doing this are available. All of them involve apportioning or allocating the number of personnel, known as a single total for the Navy as a whole, among the individual technology items, known as a total for each system. In algebraic terms, this is equivalent to the following expression:

$$aX_1 + bX_2 + eX_3 + \ldots + xX_{24} + z = R$$

where: X_1 = # of systems of type 1

a = # of personnel of skill level associated with system 1

R = number of personnel required for a year

z = number of personnel unaccounted for

With available data, 34 such equations can be written. Several methods of solving them simultaneously are available. Ordinary algebraic methods could be used, or mathematical programming or regression analysis.

For this particular formulation of a problem, algebraic methods and regression analysis are not appropriate, because we know something more about the data than is stated in the above expression. It is known that the coefficients cannot be negative or zero. If a technology system is operating, it must have some personnel to operate it. Any solution that produces negative coefficients is bound to be wrong in terms of operations, no matter how right it may be in terms of mathematics. With imperfect data, negative coefficients are often obtained so that a solution method must be chosen that will not produce negative coefficients. This leaves mathematical programming as a practical solution method.

3. Application. Linear programming is the most widely available tool, although other methods of solution could be examined and experimented with. In the work of this project, the model was formulated as follows.

The linear program used is General Electric's LINEP$ using a two-phase simplex method.

The model consists of a basic matrix drawn from the 24 systems enumerated in Illustration II-11, three vectors of manpower requirements data (one for each skill level), a vector of crew sizes, an identity matrix with 1's in the principal diagonal, 0's elsewhere, and a matrix of 1's. Each component has a different purpose, and they may be put together in different ways to change the rationale of the model, reduce its size, and eliminate redundancies and contradictions in the logic. The columns of semi-skilled, skilled, and highly skilled manpower requirements are tabulated at the right of the illustration. The counts of systems are tabulated in the other columns. Equations were written specifying minimum number of personnel and all skill levels associated with a particular class of ship. Vector J is the objective function; the solution for the objective function is specified here to account for as many personnel as possible.

ILLUSTRATION II-11

Input Vectors of Systems and Navy Manpower Requirements

YEAR	BATTLESHIPS & BATTLE CRUISERS	CARRIERS ESCORT & HELO	CARRIERS ATTACK CONV	CARRIERS ATTACK NUCL	CRUISERS CONVENTIONAL GUN	CRUISERS CONVENTIONAL MISSILE	CRUISERS NUCLEAR MISSILE	DESTROYER FRIGATES GUN	DESTROYER FRIGATES MISSILE	OTHER SHIPS	ATTACK CONV	ATTACK NUCL	BM NUCL
43	23	18	12	0	52	0	0	504	0	*3000	180	0	0
44	27	64	25	0	65	0	0	714	0	4551	235	0	0
45	27	71	28	0	79	0	0	732	0	7034	253	0	0
46	10	10	15	0	*35	0	0	*400	0	*2000	*163	0	0
47	4	8	14	0	*30	0	0	*250	0	*590	*100	0	0
48	2	7	13	0	25	0	0	146	0	485	*97	0	0
49	1	7	11	0	18	0	0	155	0	452	*93	0	0
50	1	4	11	0	13	0	0	147	0	386	*90	0	0
51	1	9	17	0	15	0	0	244	0	608	*115	0	0
52	4	10	19	0	19	0	0	299	0	641	*125	0	0
53	4	10	19	0	19	0	0	303	0	657	*120	0	0
54	4	7	20	0	18	0	0	304	0	650	*119	1	0
55	3	3	23	0	17	0	0	313	0	564	*115	1	0
56	3	3	24	0	16	0	0	320	0	499	*110	1	0
57	2	3	27	0	15	0	1	337	0	474	*108	2	1
58	0	1	26	0	13	1	1	316	0	423	*103	3	0
59	0	3	24	0	10	1	1	298	0	413	*100	6	0
60	0	3	23	0	9	4	1	267	2	401	102	9	2
61	0	4	25	0	4	6	1	223	13	403	94	13	5
62	0	6	26	0	4	8	2	237	22	434	93	15	9
63	0	6	25	0	3	11	3	219	27	432	91	16	12
64	0	6	25	0	2	18	3	214	31	429	86	19	21
65	0	7	26	0	2	20	3	221	33	432	86	20	29
66	0	8	22	0	2	22	3	216	34	455	84	22	37
67	0	8	22	0	2	29	3	215	37	464	79	28	41
68	1	8	22	0	2	29	3	215	44	457	74	33	41
69	1	8	21	0	4	29	3	220	45	441	64	43	41
70	0	7	19	1	2	29	3	178	45	347	59	47	41
71	0	7	17	1	1	29	3	171	45	348	50	53	41
72	0	7	16	1	1	29	3	172	45	273	38	57	41
73	0	7	15	1	1	29	3	115	45	232	24	60	41
74	0	7	14	1	0	29	4	*92	45	226	22	61	41
75	0	7	14	2	0	29	5	80	45	157	11	54	41
76	0	7	13	2	1					184			41
77	0	7	13	2	0					179			41

YEAR	ATK, FTR, ASW PROP	ATK, FTR, ASW JET	PROP	JET	HELO	BLMP	PROP	JET	PHASED ARRAY RADAR	MAJOR BASES	COMPUTERS 2ND GEN	COMPUTERS 3RD GEN	PERSONNEL SEMI	PERSONNEL SKILLED	PERSONNEL HIGHLY
43	*1200	0	*370	0	0	*17	*7021	0		*4900	0	0	769	392	347
44	*8200	0	*660	0	0	*29	*9652	0		*2030	0	0	1357	683	606
45	*9000	0	*900	0	5	*29	*8370	0		*2100	0	0	1494	777	717
46	*6800	0	*900	0	22	*19	*5725	0		*960	0	0	418	209	209
47	*5600	0	*610	0	30	*15	*3941	0		*490	0	0	208	111	106
48	*3850	*50	*560	0	22	12	3074	0		*340	0	0	179	90	90
49	*2380	*120	*500	0	38	16	1459	0		*236	0	0	206	99	107
50	1880	262	*480	0	68	18	1066	0		209	0	0	162	79	89
51	1061	437	*380	0	68	22	1265	97		*360	0	0	324	152	185
52	2749	778	*440	0	88	32	1749	83		*380	0	0	354	141	226
53	2382	1125	*508	*2	170	31	2164	183		*340	0	0	332	162	212
54	2449	1317	*524	*6	270	28	2055	199		*300	0	0	295	148	199
55	1896	1610	*475	*25	574	35	3734	476		*260	0	0	261	133	186
56	1783	1788	*484	*43	266	36	2174	347		*260	0	0	261	130	201
57	1448	1948	*496	*64	327	39	2087	417		*260	0	0	257	135	202
58	1834	2219	*485	*95	412	29	1454	543		*260	0	0	237	124	203
59	1360	1543	*445	*95	430	15	1227	475		*260	70	0	226	121	204
60	1156	1398	*434	*86	402	10	1060	459		*250	91	0	218	120	207
61	1080	1544	*434	*86	426	7	948	486		*260	120	0	215	127	210
62	1048	1804	*454	*86	412	0	929	517		*250	189	0	220	135	222
63	1028	1534	*452	*88	491	0	739	537		242	236	0	211	140	234
64	822	1497	*462	*88	488	0	1003	488		224	279	0	206	141	241
65	713	1474	*447	*13	499	0	911	401		*232	357	0	224	165	270
66	705	1400	*438	*62	485	0	749	550		*240	413	23	219	173	272
67	642	1450	*423	*62	501	0	725	708		247	583	61	216	178	271
68	587	1607	*403	*62	424	0	865	806		247	675	88	219	178	287
69	492	1629	*393	*62	307	0	777	919		234	706	174	188	164	255
70	403	1533	*387	*62	554	0	505	760		214	[illegible]	219	163	152	233
71	*0	*1450	*379	*66	506	0	*655	*575		202	796	225	148	143	220
72	*0	*1400	*343	*87	521	0	*530	*640		189	815	226	147	138	220
73	*0	1426	*336	*84	445	0	*410	*730		169	817	231	138	133	204
74	*0	*1370	*303	*97	431	0	*230	*830		147	821	242	133	128	197
75	*0	*1310	*280	*100	423	0	*70	*920		141	869	254	133	129	197
76	*0	*1250													
77															

With data arrayed by estimates, a series of runs was made for analysis. They are summarized in Illustration II-12. In each run, less than five technology systems assumed a non-zero value showing that most of Navy technology at any given time is closely related to a few items. It also shows the results of using incomplete and dummy data as well as the need for some ingenuity in formulating the model.

ILLUSTRATION II-12

Changes in Number of Enlisted Personnel
Accompanying Addition or Removal of One More System

RUN	WEAPON SYSTEM CHANGE	SEMI SKILLED	SKILLED	HIGHLY SKILLED	TOTAL
2	GUN CRUISERS	11,667	5,556	6,111	23,334
	NUCLEAR CARRIERS	65,000	65,000	10,000	230,000
5	BATTLESHIPS	29,987	15,225	12,015	57,227
6A					
7A	BLIMPS	4,723	2,342	4,332	11,397
	NUCLEAR CARRIERS	65,000	65,000	100,000	230,000
7	3D GENERATION COMPUTERS	511	511	787	1,809
6	DIESEL SUBMARINES	526	385	769	1,680
	FBM SUBMARINES	3,017	2,946	4,428	10,391
6B	BATTLESHIPS	26,864	13,027	8,702	47,963
	BLIMPS	3,375	1,244	670	5,289
	DIESEL SUBMARINES	526	385	769	1,680
	FBM SUBMARINES	3,017	2,946	4,428	10,391

To say that items of Navy technology are closely related to each other is to say at the same time that the variables in Illustration II-11 are highly correlated with each other. This problem arises frequently in statistical analysis and a number of procedures have been developed for dealing with them ploying a nonlinear programming code. This would be the equivalent of regression analysis with the possibility of non-negative solutions illuminated.

Another approach to analyses of highly correlated data would be formulating the model in a different way. It is now formulated in terms of a personnel balance: the sum of the people associated with each item of technology must balance approximately the sum of the requirements at each level of skill. An alternative would be a solution in terms of overall effectiveness: the sum of the effectiveness of people associated with each of the items of technology should equal the sum of the effectiveness of people associated with each level of skill required. This would involve estimating the coefficients of both sides of the algebraic expression that is the foundation of the model. This can be done, but it involves a completely different solution methodology than discussed above.

Other alternatives of both formulations and solution methodologies are available.

4. Validation. The model is forecasting unreasonably high changes in total number of personnel required with one change in a technology. As stated above, this is due partly to the structure of the data base, but mainly to the personnel balance requirement. What is very significant is the allocation of the relative mix of skills to each technology. Illustration II-13 distributes the allocation of skills by percentages associated with a few selected technologies. Retired technologies tend to have been allocated a skill mix of over 50 percent semi-skilled with the remainder evenly allocated to skilled and highly-skilled. When skill groups are summed by percentage over all technologies and all years they validate extremely well with Illustration II-14 which are plots of the skill group percentages of actual requirements. For example, 3rd generation computers entered the fleet in 1971-72. When the allocated percentages are compared to the actual average mix it compares favorably with 30, 28, and 42 percent for semi-skilled, skilled and highly-skilled respectively.

ILLUSTRATION II-13

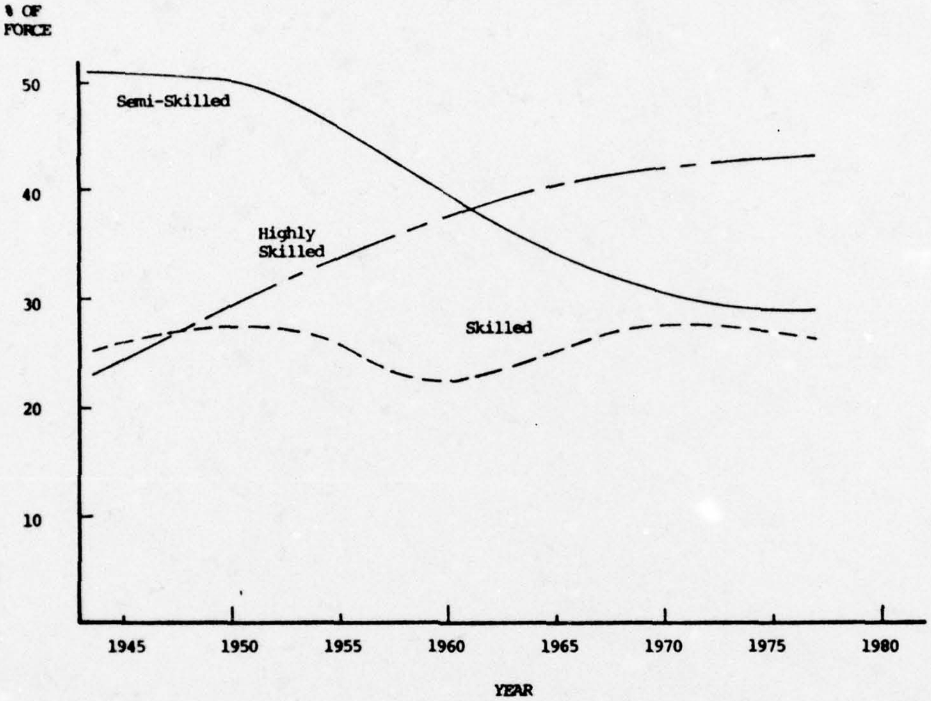
Enlisted Personnel by Percentage at Various Skill Levels Associated Navy Wide With Various Technologies

	Percentages*		
Technology	Semi-Skilled	Skilled	Highly Skilled
Battleships	52	27	21
Gun Cruisers	50	24	26
Diesel Submarine	31	23	46
Blimp	63	24	13
Nuclear Carrier	28	28	44
3-D Generation Computer	28	28	44
Ballistic Missile Submarine	29	28	43

* Personnel for a technology include operators, crews, closely associated weapons, support, and related activities in the U.S. Navy.

ILLUSTRATION II-14

Changes in Mix of Enlisted Personnel Requirement



E. Timing of Forecasts

The timing and form of needed manpower requirements forecasts vary with the user and his position in the development process or acquisition cycle. OP-01's asserted need for a macro-level forecast of advanced technology manpower exists before the technology is specified as a component or system. The forecast of highly-skilled, skilled, and semi-skilled requirements will provide a rationale for discussions with program sponsors on trends in skill mix, the aggregate impact of independently generated future requirements, and OP-01's relative ability to balance authorizations among air, sea, and subsurface sponsors.

Weapon designers have no express need for manpower skill forecasts, but can use data on the supply of naval personnel by human factors engineering characteristics. These human factors are design points for component development, independent of any association with a system. Usually a system is characterized in the development cycle by its critical component which will be combined with previously specified components. The complement of components determines manpower requirements which suggests the need for forecasts may be

well before the critical component technology entrance into 6.3 if it will likely result in a system increment as opposed to a replacement system.

Manpower forecasts for the major system acquisition cycle takes several different forms characterized by successively greater detail with respect to numbers and skills required. Illustrations II-15a and II-15b depict a representative program acquisition and the points and types of manpower data needed. Only points 1 and 2 are true forecasts. Points 3 and 4 are relatively late in the cycle and require timely action to address needed changes. Illustration II-15b explains the significant terms in II-15a.

ILLUSTRATION II-15a

Combatant Ship Acquisition Event Phasing and Synchronization (Representative)

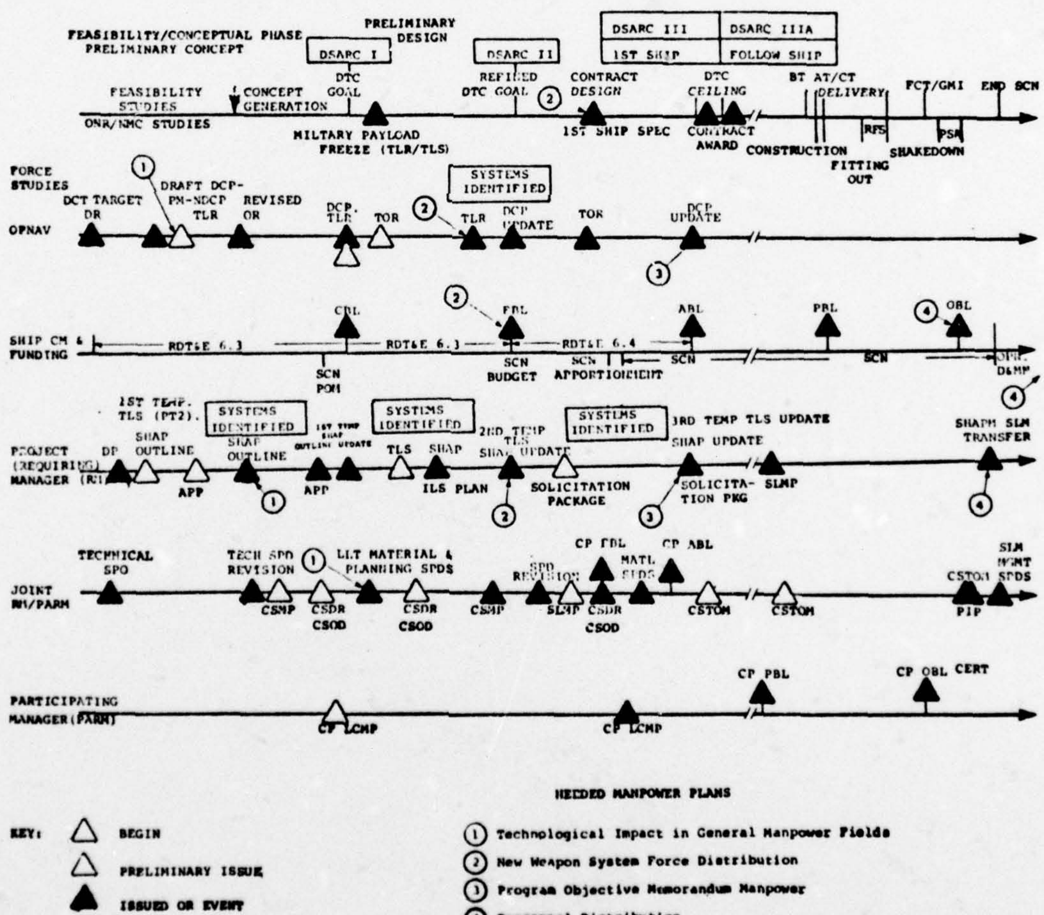


ILLUSTRATION II-15b

Combatant Ship Acquisition Procedures

MILESTONES 0 1 2 3

RESPONSIBILITY	CONCEPTUAL	VALIDATION	ENGINEERING	PRODUCTION
ONR/NMC	Feasibility Studies Concept Generation Design to Cost Goal	Preliminary Design Refined Design to Cost Goal	Contract Design 1st Ship Spec Design to Cost Ceiling (2)	Construction Fitting Out Shakedown
OPNAV	Force Studies Target Directive Draft Decision Conditioning Paper Operational Requirements Top Level Requirements (1)	Tactical Operational Requirement Top Level Requirement Decision Coordinating Paper Update (2)	Tactical Operational Requirements Decision Coordinating Paper Update (3)	Operational Exceptance (4)
FUNDING	RDT&E 6.3 Shipbuilding and Conversion Navy Conceptual Base Line	RDT&E 6.3 Functional Base Line Shipbuilding and Conversion Navy Budget (2)	RDT&E 6.4 Allocated Base Line	RDT&E 6.4 6.6 Production Base Line Operational Support Base Line (4)
PROJECT MANAGER (RM)	Development Proposal Advanced Procurement Plan Ship Acquisition Plan Outline 1st Test & Evaluatation Master Plan (1)	Top Level Specs. Ship Acquisition Plan Integrated Logistic Plan 2nd Test & Evaluatation Master Plan (2)	3rd Test & Evaluation Master Plan Solicitation Package (3)	Ship Acquisition Project Manager Transfer (4)
RM/PARM	Ship Project Directive Combat System Design Requirement Design (1)	Long Load Time Specs. Combat System Management Plan Ship Project Directive Revision	Combat System Design Ship Logistic Management Plan Material Ship Project Directive	Combat System Tactical Operational Manual Program Integration Package
Participating Manager (PARM)	Computer Program Life Cycle Management Plan	Computer Program Life Cycle Management Plan	Computer Program Product Base Line	Computer Program Operational Support Base Line

III. SUMMARY

This study investigates the feasibility and usefulness of forecasting techniques applied to the manpower requirements and research and development planning and programming cycles. A major thrust of the effort is directed towards creating data bases in computer and nuclear manpower requirements from 1950 to the present, 3rd generation computer, nuclear, laser, and electro-optics technologies, and 24 weapon systems (aircraft, ships, and bases) from 1946 to the present. Three methodologies are used to forecast manpower requirements for emerging technologies. Growth curves and historical analogies are used to forecast manpower requirements based on similarities between existing and emerging technologies which are useful in validating more complex forecasting techniques. A system disaggregation technique is used to analogize manpower requirements on a component by component basis compared between an existing reference system and a perceived application of a new technology. A linear program allocates manpower over a 30-year period to forecast changes in the number of skills required by the addition or deletion of technology represented in the 24 weapon system types.

IV. CONCLUSIONS

A. Task 1

Historical analogy allows a few "casual" similarities between past and future characteristics to control the predicated outcome so as to be analogous.

Historical analogy allows the introduction of forecasters bias by limiting the outcome to a limited set of existing comparison technologies.

Projection by analogy is well suited for technologies that will be constrained by known policy sets with respect to one or more causative characteristics such as the number of platforms displaced or mandatory contractor maintenance.

B. Task 2

Functional disaggregation is the most reliable of the three methodologies and is equal to the reversed pruned tree network analysis in clarity and exactness.

The functional disaggregation methodology is limited to a single system at a time step-wise analysis; it addresses first eschelon personnel only.

The disaggregation methodology is useful only when the application of the new technology can be reasonably perceived, usually mid-way during the advanced development phase.

Functional disaggregation methodology requires a higher degree of expertise with the involved technology than most other forecasting techniques.

C. Task 3

Total Force Modified Linear Program Methodology is more favorable to the manpower planner than individual systems methodologies for its ease of use, its generalized expandable data base, and apparent reliability.

The Modified Linear Program is of little use to the weapon planner's assessment of his system's explicit manpower requirements.

The Total Force Methodology percentage allocations of gross skill groups are very reliable forecasts based on the comparison of the present requirements.

A 20-year span exists between the introduction of technology into Advanced Development (late 6.3), which coincided with commercial introduction, and a specification of a skill explicitly related to that technology.

The All Volunteer Force policy of the elimination of jobs perceived as less desirable has influenced the current ratio of 75 percent of total manpower requirements being deemed skilled or highly skilled.

Despite the CNO policy goal of reduced manpower, in part through technology, the great diversity of present and future technology tends to narrow billet classification and therefore broaden skill requirements.

D. Task 4

The weapon planner's needs for human factors data is decidedly different than manpower planner's needs for assessing the impact of the technology on force levels and skills.

The weapon designer's orientation of engineering a system towards such things as specific color and space acuity, eye-hand coordination, upper body strength is not supported by the methodologies herein, nor anywhere in the literature.

Manpower planners need force level by skill forecasts in advance of technology completing exploratory development.

V. RECOMMENDATIONS

The macro-linear programming forecasting technique should be further exercised with specific attention to the following tasks:

- Complete the historical table of systems counts.
- Consider redefining the aircraft as "aircraft in squadrons."
- Determine whether the impact of a vessel on requirements should be considered as beginning on date of commissioning or date of launch.
- Extract from the files, the manpower requirements for all 34 years under consideration.
- Rerun the data as was done here using a larger linear programming routine, preferably the routine employed by Control Data Corporation.
- Explain the effect of solutions with alternate formulations, transformations of data, and alternate solution methodologies.

BIBLIOGRAPHY

BIBLIOGRAPHY

- - - - -, Manpower Impacts of Industrial Technology, New York State Department of Labor, 1970.

Agarwal, S.P., Manpower Demand, Meerut, India, 1970.

Bartholomew, D.J., et al., Some Statistical Techniques in Manpower Planning, CAS Occasional Papers #15, HM Stationary Office, London, 1970.

Blaug, OECD Occupational and Educational Structures of the Labour Force and Levels of Economic Development OECD, 321 pp., 14 refs. 1970.

Demaree, R.G. and Marks, M.R. et al., Development of Qualitative and Quantitative Personnel Requirements Information, Technical Report No. AMRL-TDR-62-4, December 1962 (AD 296 997).

Doeringer, Peter B. and Prose, Michael J., Internal Labor Markets and Manpower Analysis, Heath, Massachusetts, 1971.

Dunnette, M.D., Work and Non-Work In The Year 2001, University of Minnesota, California, 1973.

Freeman, C., This Measurement of Scientific and Technological Activities, UNESCO Statistical Reports and Studies, 63 pp., 33 refs. 1969.

Gilchrist, W., Statistical Forecasting, John Wiley, New York, 1976.

Haase, P.E., Technological Change and Manpower Forecasts, Industrial Relations (California U), 5(3)59-71 14 refs. 1966.

Jackson, William, Lord Jackson, Manpower for Engineering and Technology, British Association for Commercial and Industrial Education, London, 1969.

Kelly, S.C., Chirikos, T.N., and Finn, Michael, G., Manpower Forecasting in the U.S.: An Evaluation of the State of the Art, Center for Human Resource Research, Ohio State, Columbus, 1975, (for Dev. Soc. Sys. and Human Resources, NSF).

Laslett, R.E., A Survey of Mathematical Methods of Estimating the Supply of and Demand for Manpower Engineering Industry Training Board, Occasional Paper No. 1, London, 1972.

McCarthy, M.C., The Employment of Highly Specialized Graduates: A Comparative Study in the U.S.A. and the U.K., D.E.S. Science Policy Studies, 3 HMSO, 36 pp., 31 refs. 1968.

Potter, N.R. and Dieterly, D.C., Methods for Predicting and Assessing The Impact of Technology on Human Resource Parameters, AFHRL-TR-74-71, August 1974.

Stainer, G., Manpower Planning: The Management of Human Resources, Heineman, 1971.

APPENDIX

CODES USED IN DATA TABLES AND ON CHARTS

A.	Chart	Office of Naval History
B.	Report	House Armed Services Committee
C.	Tables	DoD Comptroller
D.	Book	Janes
E.	Pamphlet	Navy Comptroller
F.	Book	Navy Aviation History Office
G.	Book	Janes
H.	Report	GSA
J.	Slides	Navy Data Systems Command
K.	Report	Sec Navy
L.	Memo	For Navy Program Planning Office
M.	Charts	BuPers
N.	Report	Admiral King
P.	Book	U.S. Warships WWII
Q.	Report	Naval Avn Log Summary
R.	Book	Naval Avn History Office
S.	Tables	DoD Comptroller
T.	Journal	Intl Defense Review
U.	Tables	DoD Comptroller
V.	Book	Morrison
W.	Paper	Tim Kane - Morrison
X		See Q

DATA TABULATIONS

BATTLESHIPS AND BATTLECRUISERS

YEAR \ SHIP	(A)	(B)	(C)	(D)	(E)	(L)	(KNP)	(V)	*
				BB	BB		BB		
	BB			CB			CB		
43								23	23
						23	15	27	27
45	23						8	27	27
	10						-2		10
	4								4
	2								2
	1								1
50	1								1
	3								3
	4								4
	4								4
	4								4
55	3								3
	3								3
	2								2
	0								
	0								
60	0								
	0								
	0								
	0								
	0								
65	0								
	0								
	0								
	1	1	1	1	1				1
	1	1	1	1					1
70	0								
	0								
75									
77									

CRUISERS

	(A)	(B)			(C)	(D)					(E)		(K)		
Ship Year	CB CA,CL CDG,CLG CG,CGN	CA CL	CG DLG* CLG	DLGN CGN	Cruisers	CA CL	CLG DLG CG	DDS DLGN CGN	CC CA CG CGN CLG	(New Def)	DL DLG DLGN	FF FFG (New Def)	CB	CA	CL
43															
													2	17	42
45	71														
	?														
	?														
	25														
	18														
50	13														
	15														
	19														
	19														
	18														
55	17														
	16														
	16														
	15														
	12														
60	13				13				14	14	7	41			
	12	4	16	0	12										
	13	4	18	0	13										
	14	3	23	1	14										
	14	2	30	1	14				16	28	25	40			
65	14	2	32	1	14										
	14	2	38	1	14										
	13	2	37	2	13										
	13	2	36	2	13	4	26	3	15	34	31	50			
	13	4	32	2	13	4	26	3							
70	10				10	2	25	3	10		25				
	10				9	1	25	3	9		27				
					9	1	25	3	9	28	28	66			
					9	1	25	3	9		28				
					7	0			7		29	64			
75					27					27		64			
										26		64			
77										27		64			

Cruisers (Continued)

(L)	(T)		(KNP)		(V)			
Ship	FF(N)	CB	CA	CL	CA CL	CA CL DL FF	* CLG DLG FFG	DLGN
Year					52	52	-	-
72		0	18	19	65	65	-	-
		0	-10	0	79	79	-	-
		2	13	33				
						4		
						4		
						3	1	
						2	1	
						2	1	
						2	1	
						2	2	
						2	2	3
						4	2	3
						2	3	3
						1	3	3
						1	3	3
						1	3	3
	4							4

DESTROYERS AND FRIGATES

	(A)		(B)		(C)		(D)		(E)			
Ship	DD,DL DDE,DDR DDG,DLG DLGN	DE DER DEG	DD,DE DL,LFR IFS	DDG DEG DLG* DLG	Destroyers Frigates	DE DER	DL DD DE LFR IFS	PF(109) DLG* DEG DDG	DD DDR	DD DDR (New Def)	DDG	DDG (New Def)
Year												
43												
45	372	365										
	134	12										
	143	12										
50	137	10										
	206	38										
	243	56										
	247	56										
	247	57										
	249	64										
	250	70										
	253	84										
	245	71										
	237	61										
60	226	41			226				218	223	1	3
	223	41	231	-2	223							
	240	68	270	3	240							
	226	40	225	7	226							
	225	40	214	11	225				179	184	21	29
65	234	39	237	13	227							
	232	42	230	16	274							
	237	46	246	22	283							
	240	50	244	24	290				181	184	28	37
	222	43	227	25	265		234	45				
70	176	47			223		199	45	122		29	
	173	61			216		184	45	103		29	
					216		167	45	93	93	29	38
					195		160	45	71		29	
					154				32	32	29	37
75					134		125	45		32		38
										31		38
										24		39
77												

OTHER SHIPS

Ship Year	(A) MINE	(A) PATROL	(A) AMPHIB	(A) CMD & AUXIL	(A) (TOTAL)	(B) TOTAL SHIPS	(C) MINE	(C) PATROL	(C) AMPHIB	(C) URG	(C) AUXIL	(C) (TOTAL)	MINE	PATROL
43														
	618	1469	3307	1640	7034									
	54	50	136	245	485									
	52	50	120	230	452									
50	56	33	79	218	386									
	91	40	208	269	608									
	114	29	189	309	641									
	121	23	226	287	657									
	117	22	223	288	650									
	112	15	175	262	564									
	113	11	139	236	499									
	104	12	134	224	474									
	77	12	121	213	423									
	82	6	120	205	413									
60	81	4	113	197	401		81	4			197	283		
	83	4	110	206	403	345	89	6			276	371		
	84	2	130	218	434	374	89	6			265	360		
	84	0	132	216	432	400	87	6			264	357		
	84	0	133	212	429	376	85	6			263	354		
65	84	0	135	213	432	383	85	6			262	353		
	84	0	159	212	455	408	84	4	159	75	171	493		
	83	3	162	216	464	424	83	7	162	78	176	506		
	84	6	157	210	457	412	84	9	157	75	176	501	99	124
	74	7	153	207	441	423	74	9	153	77	168	481	81	29
70	64	15	97	171	347		64	16	97	68	126	371		
	59	17	95	177	348		42	17	78	59	121	317		
							31	16	77	59	94	277	84	37
							11	14	66	58	90	239	45	39
							9	14	65	49	86	223	38	37
							3	14	64	43	80	204	36	34
75													25	14

OTHER SHIPS (Continued)

(D)						(E)					(K)		
			AUXIL										
AMPH	CMD & COMMO	URG	LOG SPT	FLT SPT	(TOTAL)	MINE	PATROL	AMPHIB	AUXIL	(TOTAL)	MINE	PATROL	AUXIL
						81		113	197	388			
						84	4	133	212	427			
156	5	96	124	128	732	86	6	157	[208]	457			
142	5	87	117	149	610	74	[10]	153	207	444			
86	1	75	101	109	494	64	16	97	194	364			
65	1	62	96	89	397	42	17	79	179	310			
64	1	83	91		390	34	16	77	153	273			
57	1	61	29	83	301	11	14	66	148	232			
						9	14	65	135	216			
57	1	49	42	77	265	3	14	64	123	197			
						3	8	63	116	184			
							8	62	116	179			

OTHER SHIPS (Continued)

(L)					(V)					
MINE	PATRL	AMPH	AUXIL	(TOTAL)	MINE	PATL	AMPH	AUXIL	(TOTAL)	*
					194	96	103	413	806	806
611	1469	1256	1215	4551	291	134	340	654	1419	1419
					317	141	468	877	1803	1803

ATTACK SUBMARINES

	(B)		(C)		(D)		(K)	(V)	(L)	(KNP)	(AA)			*	*
Ship	SS	LPSS	SSN	SS	SS	SSN	SS	SS	SS	SS	SSN	SS	SSN	SSN	SS
				(-SSBN)	LPSS SST AGSS										
Year															
43								180				180			180
							235	233	237			235			235
								257		100		255			253
										-51 = 252					(160)
										203					(100)
															(97)
50															(93)
															(90)
															(115)
															(125)
															(120)
											1			1	(119)
55											1			1	(115)
											1			1	(110)
											2			2	(108)
											3			3	(103)
											6			6	(100)
60			9	102							9	102	9	9	102
	92		13	97							13	94	13	13	94
	88	2	15	94							14	93	15	15	92
	86	2	16	91							15	91	16	16	91
	83	2	19	85							18	86	19	19	85
65	83	2	20	85							20	86	20	20	85
	83	2	22	82							20	84	22	22	83
	77	2	28	77							26	79	28	28	78
	72	2	33	72							31	74	33	33	73
	61	2	39	62	74	45					38	64	43	43	62
70			46	59	66	47					46	59	47	47	59
			51	50	49	54					50	50	53	53	50
			56	38	35	57					57	38	57	57	38
			60	24	25	60					59	24	60	60	24
			61	12							62	12	61	61	12
75			64	11	12	64					63	11	64	64	11
77															

STRATEGIC SUBMARINES

Year	Ship	(A) NB SSG SSGN SSBN	(C) SS	(D) SSBN	(E) SSBN	(G)	*
43							
50							
		1					
		1					
		2					
		2					
		1					
		2					
		2					
		2					
		4					
60		7			2	2	2
		10				5	5
		14				9	9
		17				12	12
		23			21	21	21
65		30				29	29
		37	37			37	37
		41	41		41	41	41
		41	41	41	41	41	41
		41	41	41	41	41	41
70		41	41	41	41		41
		41	41	41	41		41
			41	41	41		41
			41	41	41		41
			41		41		41
			41	41	41		41
					41		
77					41		

AIR SQUADRONS

Squad. Year	NAVY	ATK %	MC	ASW (VS/HS) NAVY	(E) PATRL (VP) NAVY	RECON NAVY	NAVY	HELO %	MC	OTHER NAVY	MC	TOTAL NAVY	JET	(R) USMC PROP	VMO VMR	%	T
43																	
45														103	25	(4)	
														27			
														21			
													2	19			
													2	19			
50													4	19			
													5	12			
													5	16			
55																	
													COMBAT SQUADRONS (RCCE, HELO (OTHER OUT) USN	USMC	USN	SUPPORT SQUADRONS (RECCE & OTHER)	
60	79	25	26	25	30	--	2	84	11	26	10	162	134	26	26	28	
	84	23	26	27	30	2	3	83	15	20	9	166	141	26	22	29	
65																	
	81	25	27	24	30	11	7	74	20	28	19	181	135	27	39	33	
70	74	25	25	20	24	10	7	72	21	29	19	164	118	25	39	33	
	67	27	25	20	24	9	7	73	19	29	19	156	111	25	38	33	
	68	26	25	21	24	20	5	78	18	34	20	172	113	25	54	27	
	70	26	25	18	24	10	5	79	19	34	20	161	112	25	44	31	
	70	27	26	18	24	9	5	81	22	34	9	160	112	26	43	17	
75	70		25	20	24	8	4		23	38	9	164	114	25	46	16	
	65		25	21	24	9	4	85	23	39	9	162	110	25	48	16	
77	65	28	25	22	24	8	4	84	22	38	8	161	111	25	46	14	

COMBAT PLANES

(S)*
ACTIVE INVENTORY

Year	A/C (R) ON HAND COMBAT	PATROL* JET	PATROL* PROP	ASW* JET	ASW* PROP	ATTACK JET	ATTACK PROP	FIGHTER JET	FIGHTER PROP	(TOTAL) (JET)	(TOTAL) (PROP)	(TOTAL)
43	8696		1382		352		3678		3284		(8696)	8696
	2116		2935		870		7873		10438		(22116)	22116
45	9125		3710		1230		9407		14778		(29125)	29125
	4637											
	1181											
	9899											
	9372											
50	9422		696			15	1344	491	3306	506	2800	3306
	8713		904		786	36	955	820	3715	856	6360	7216
	8742		965		1056	45	1150	824	3770	869	6941	7810
	8818		973	1	1048	74	1338	2375	2450	2450	5809	8259
	8829		1000	100	776	127	1468	3032	1422	3259	4666	7925
55	8884		1004	305	525	123	1786	3487	633	3915	3948	7863
	7961		905	449	155	137	1749	3726	113	4312	2922	7234
	7591		832	542	2	316	1466	3482	37	4340	2337	6677
	7408		729	594		1027	1131	2694	9	4315	1869	6184
	7030		705	602		1232	857	2210		4044	1562	5606
60	6074		656	601		1326	726	1718		3645	1382	5027
	6305		621	510		1279	552	1797		3586	1173	4759
	6420	7	638	659		1412	518	1768		3846	1156	5002
	6265	42	602	452		1515	432	1482		3491	1034	4525
	5420	82	522	423		1483	406	1360		3348	928	4276
65	5127	130	437	423		1535	275	1277		3365	712	4077
		176	400	429		1551	236	1199		3355	636	3991
		228	336	374		1662	169	1185		3449	505	3954
		245	296	337		1777	57	1231		3590	358	3943
		263	234	291		1534	20	1185		3011	254	3265
70		294	143	232		1643	1	1146		3315	144	3459
		318	138	184		1620	1	1041		3163	139	3302
		325	118	181		1517		962		2985	118	3103
		331	91	168		1560		936		2995	91	3086
		341	63	153		1441		894		2829	63	2892
75		355	41	137		1438		752		2682	41	2723

77
*x for 43-45

COMBAT PLANES (Continued)

(x) NAVY ONLY JET	PROP	TOTAL	* JET	PROP	TOTAL
0			0		*1200
0			0		*8200
0			0		*9000
0					*6800
0					*5600
0			*50		*3900
			*120		*2500
262	1880	2142			
437	1861	2298			
778	2749	3527			
1125	2382	3507			
1317	2449	3766			
1610	1896	3506			
1788	1783	3571			
1948	1448	3396			
2219	1834	4053			
1543	1360	2903			
1398	1156	2554			
1544	1080	2624			
1804	1048	2852			
1534	1028	2562			
1497	822	2319			
1474	713	2187			
1400	705	2105			
1450	642	2092			
1607	587	2194			
1629	492	2121			
1533	403	1936			
			1450	0	*1450
			1400	0	*1400
			1420	0	*1420
			1370	0	*1370
			1310	0	*1310
			1250	0	*1250

SUPPORT PLANES

A/C	(R) ON HAND OBSN	TRANS & UTIL	TOTAL	(S) WARNING JET	WARNING PROP	KC130's & TRANS JET	KC130's & TRANS PROP	OBSN PROP	OTHER PROP	(TOTAL) (PROP)	(TOTAL) (JET)	(TOTAL)	(S') (PROP)	(JET)	(TOTAL)
Year															
43		878	878												
		1939	1939												
45		2897	2897												
		2864	2864												
	413	1288	1701												
	299	1295	1594												
	144	1272	1416												
50	126	1193	1319			-	436	124	33	593	-	593			
	101	775	876			-	531	28	51	610	-	610			
	136	971	1107			-	513	43	54	670	-	670			
	194	1250	1444	2	20	-	603	66	50	739	2	741			
	237	1276	1513	9	15	-	584	61	47	707	9	716			
55	217	1299	1516	39	2	-	570	50	58	680	39	719			
	233	1231	1464	58		-	592	60	51	703	58	761			
	164	1287	1451	105		-	590	52	51	693	105	798			
	160	1307	1467	133		-	534	45	36	615	133	748			
	150	1355	1505	124		-	533	48	22	603	124	727			
60	135	1320	1455	120		-	514	45	15	574	120	694			
	129	1285	1414	109	136	4	491	40	9	676	113	789			
		1670	1670	96	126	11	460	38	114	738	107	845			
		1639	1639	95	125	11	436	33	67	661	106	767			
		1727	1727	110	121	15	454	24	53	652	125	777			
65	20	1681	1701	88	96	15	449	18	54	617	103	720			
				47	130	15	437	11	48	626	62	688			
				57	124	24	417	18	47	606	81	687			
				60	119	33	399	55	43	616	93	709			
				63	119	29	395	113	45	672	92	764			
70				61	115	28	355	93	36	599	89	688			
				72	103	27	288	102	19	512	99	611			
				99	82	22	271	89	20	457	121	578			
				102	66	21	244	89	17	411	123	534			
				95	38	23	235	80	13	366	118	484			
75				99	28	24	225	77	15	345	123	468			
77															

MAJOR INSTALLATIONS

Base Year	(E) NAVY OPERATING BASES US	O'S	TOTAL	NAVY TOTAL US	OS	USMC (TOTAL)	(Q) USN&USMC US	OS	(TOTAL)	(U) ALL (NOT JUST) US	OS	(TOTAL)	NAVY US&OS
43													
45													
							208	52	260				236
50							189	43	232				
55													
60													
	64	27	(91)	205	61	(266)							242
	66	25	(91)	203	56	(259)							224
65										916	136	1052	
										896	124	1020	
				210	61	(271)				967	120	1087	247
	72	27	(99)	210	61	(271)	20	4	(24)	960	109	1069	247
				205	52	(257)				966	107	1073	234
70	59	25	84	188	49	(237)				933	110	1043	214
			75			224			22	791	103	894	202
			69			213			24	762	99	861	189
			66			195			26	752	97	849	169
			58			171			24	725	93	818	147
75			56			185			24	683	92	775	161
			57			189				673	91	764	165
			57			188							165

BLIMPS AND MISCELLANEOUS

Misc. Year	(R) ON HAND	%	(X) ACTIVE USN ONLY	(Z)	(R) ON HAND MISC	% ACTIVE	(*) ACTIVE BLIMPS
43	78				96		
	146				364		
45	139			50	520		
	93				1006		
	66				779		
	56	22	12		545		12
	59	27	16		150		16
50	58	31	18	58	203		18
	58	37	22		357		22
	59	54	32		371		32
	50	62	31	50	704		31
	47	60	28		1381		28
55	61	57	35		2361		35
	51	(61)	36		2752		36
	54	(67)	39		1521		39
	42	69	29		648		29
	37	41	15		468		15
60	18	56	10		800		10
	14	50	7		1147		7
	13				1210		
					970		
					1290		
65					968		
70							
75							
77							

COMPUTERS

Year	(H) Comp. SYSTEMS GNL MGT	SPEC 1▲L	(TOTAL)	UNITS	OWNED	CPU'S LEASED	CONTR		3D GEN	(J) COMPUTERS TOTAL	2D GEN
43											
45											
50											
55											
				54	70					70	70
60				67	91					91	91
				87	138					120	120
				90	178					189	189
				123	236					236	236
				134	278					279	279
65				119	324					357	357
				203	259	180		(439)	23	436	(413)
	567	77			413	231		(644)	61	644	(583)
	659	104			499	244	20	(763)	88	763	(675)
	665	158			529	271	23	(823)	174	880	(706)
70	611	317			582	293	19	(894)	218	912	(694)
	527	394			779	222	20	(1021)	225	1021	(796)
	535	507			930	207		(1137)	226	1041	(815)
	519	510			934	206		(1140)	231	1048	(817)
	486	595			1040	196		(1236)	242	1063	(821)
75	487	623			1115	189		(1304)	254	1123	(869)
	475	654			433	173		(1336)	270	1147	(877)
77											

PERSONNEL REQUIREMENTS BY SKILL LEVEL

YEAR	SEMI	% SKILL	HIGH	TOTAL PERS ON BOARD	ESTD PERS RQMT SEMI	SKLD	HIGH	TOTAL	RQMT AS % OF ACTUAL	SHORT IN RQMT COUNT
43	51	26	23	1508	769	392	347	1508		
4				2600	1357	683	606	2646	+1 3/4%	
45	50	26	24	2988	1494	777	717	2988		
6	50	25	25	835	418	209	209	836		
7	49	26	25	425	208	111	106	425		
8	50	25	25	358	179	90	90	359		
9	50	24	26	411	206	99	107	412		
50	49	24	27	331	162	79	89	330		
1	49	23	28	662	324	152	185	661		
2				736	354	141	226	722	-1 9/10	
3	47	23	30	706	332	162	212	706		
4	46	23	31	642	295	148	199	642		
55	45	23	32	580	261	133	186	580		
6	44	22	34	592	261	130	201	592		
7				598	257	135	202	593	-5/6	
8	42	22	36	564	237	124	203	564		
9	41	22	37	552	226	121	204	551		
60	40	22	38	544	218	120	207	545		
1	39	23	38	552	215	127	210	552		
2				584	220	135	222	577	-2	
3	36	24	40	585	211	140	234	585		
4	35	24	41	587	206	141	241	588		
65	34	25	41	659	224	165	270	659		
6	33	26	41	664	219	173	272	664		
7				674	216	178	271	664	-1 1/2	
8	32	26	42	684	219	178	287	684		
9	31	27	42	606	188	164	255	607		
70	30	28	42	542	163	152	233	548		
1	29	28	43	511	148	143	220	511		
2				490	147	138	220	505	+3 1/20	
3	29	28	43	475	138	133	204	475		
4	29	28	43	457	133	128	197	458		
75	29	28	43	*459	133	129	197	459		
6	29	27	44	460	133	124	202	459		
7				461	130	113	213	456	-1 1/10	

NAVY PERSONNEL

	(F) REQUIRED					(M)
YEAR	UN RATED	SEMI SKILLED	SKILLED	HIGHLY SKILLED	(TOTAL)	ACTIVE DUTY
43						1508
	1.154	203	683	606	2646	2600
45						2988
						835
						425
						358
						411
50						331
						662
	312	42	141	226	722	736
						706
						642
55						580
						592
	257		135	202	593	598
						564
						552
60						544
						552
	220		135	222	577	584
						585
						587
65						659
						664
	171	45	178	271	664	674
						684
						606
70						542
						511
		147	138	220	505	490
						475
						457
75						
						460
77	105	25	113	213	456	

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